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Abstract Formulation of Data Processing Problems

by **JOHN W. YOUNG, JR., and HENRY K. KENT**

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THERE are three stages in the application of high speed digital computers to data processing problems:

1. Systems Analysis—the task of determining what is to be done
2. Programming—a statement of how it is to be done
3. Coding—a translation of this statement into machine language

A wide variety of automatic coding techniques have been developed. This paper presents a first step in the direction of automatic programming as well as a tool which should be useful in systems analysis.

Since we may be called upon to evaluate different computers or to find alternate ways of organizing current systems, it is necessary to have some means of precisely stating a data processing problem independently of mechanization.

The notation presented here provides such a precise and abstract way of specifying the informational and time characteristics of a data processing problem and should enable the analyst to organize the problem around any piece of hardware. This notation could be used in the input to a new type of automatic programming system in which a problem is stated not only independently of machine, but without specifying the structure of files or sequence of operations where such specification is not needed for logical correctness. Further, the application of a graphical version of the notational system will show the relationships among information in input and output so that redundancies can be eliminated and alternative ways of processing studied.

The context of our analysis is that the objectives of the data processing system have been stated in terms of the required outputs; these outputs are not considered as subject to revision. On the other hand, although the inputs may be organized in any desired fashion it appears necessary or at least convenient to state one of the possible input organizations from which any equivalent one can be derived. It should be noted that the input may supply any one of a number of equivalent pieces of information, e.g., either customer name to be copied directly onto an output or an identification number from which the name can be looked up.

BASIC COMPONENTS OF DATA PROCESSING PROBLEMS

A data processing problem can be described in terms of four kinds of basic components:

1. Information sets
2. Documents
3. Relationships
4. Operational requirements

INFORMATION SETS

An information set which we call P_i is a list of all possible items belonging to the same class. From the items in these lists are drawn the data which will flow through the system. The members of an information set may be considered as all the possible entries which could be made in a specified blank on a document. Examples of information sets are customers' names and addresses, part numbers, unit prices, dates, invoice numbers, etc. Whether an information set or a collection of related information sets exists in the system as a file will depend on the ultimate mechanization of the problem. As far as an abstract statement of this phase of problem is concerned, it is necessary to state only the information sets and their relationships. Governed by these relationships the analyst is then free to choose whatever file structure will make the over-all system most efficient.

DOCUMENTS

A document, which we call D_j, is a collection of related information items, D_{jk} where k is the number of the items on the jth document. Documents are either inputs or outputs; examples are shipping notice, invoice, daily sales report, etc.

RELATIONSHIPS

The third element which must be described is the set of relationships among the information sets, the documents, and the items on the documents. A relationship between information sets specifies the correspondence between the items in one set and the items in some other set. For example, relationships exist between the corresponding items of the set of customers' names and customers' numbers, salesman's names and customers, day-month-year's and dates, etc.

The relationship which shows how an item on an output document is derived, or from where it is taken if it is simply copied from another document, is called the defining relationship. In addition, there are producing relationships which define under what stimuli the documents or certain items on the documents are produced,

and conditional relationships which specify under what conditions any of the foregoing apply.

OPERATIONAL REQUIREMENTS

The final element in a data processing problem is the set of operational requirements of the system. These are the requirements which are not related to the logic of the problem, such as the volume of input documents per day, the number of copies of outputs, the size or color of the documents, the elapsed time between the receipt of an input and the production of an output, etc.

ABSTRACT STATEMENT OF A PROBLEM

An abstract statement of a problem can be made by preparing two lists: one of the information sets and the other of the documents.

The list of information sets presents the name of each set along with certain data about the number of items in each set, the number of characters required for each item, and the qualitative and quantitative relationships among sets. The list of documents presents for each document the items on the document and the information set each item belongs to. It also lists the defining and producing relationships for each item on the documents as well as the operational requirements associated with the documents.

Thus the output documents are completely specified in terms of the transformations which are applied to the inputs. At the same time, the relationships among the information sets enable logical substitutions to be made in the input to achieve the same output.

In order to describe the notation and its properties, we will proceed by means of an illustrative example.

VERBAL STATEMENT OF PROBLEM

Suppose that we have a manufacturer who maintains stock at several scattered warehouses. Sales are made and reported to the warehouses, which in turn make the shipments and at the same time send information to the central office for billing purposes. The central office sends invoices to the customers, receives payments, furnishes monthly statements, and prepares a daily cumulative sales report for management purposes. Each customer is served by a given salesman who in turn works out of a given warehouse.

There are five documents in this system, two inputs (shipping notice, customer payment) and three outputs (invoice, monthly statement, daily cumulative sales report).

Three hundred shipping notices are received daily and each has, on the average, five line items. An invoice is prepared for each shipping notice. After determining the unit price and extended price for each line item, the total price per shipment is calculated. The invoice must be sent within two days after receipt of the shipping notice.

About two hundred payments are received daily, each covering on the average one invoice. The customer includes the invoice number with the payment.

Monthly statements are sent out between the tenth and the fifteenth of the month to all customers with an open balance as of the tenth of the month. The invoices which were dated after the tenth of the previous month and which have not yet been paid are itemized on the statement. Old unpaid invoices are consolidated and shown only as an old balance.

The daily sales report is produced within two days after the close of business. It includes the gross sales for the date and a breakdown by salesman of daily sales and cumulative sales for the past month.

An abstract statement of this problem is presented in Table 1 (List of Information Sets) and Table 2 (List of Documents). A graphical representation of the information sets is presented in Figure 1 and a combined graphical representation of both the information sets and documents is presented in Figure 4.

TABLE 1

Information Sets

		n	L	Relationships
P_1	Date	—	$6N$	$P_1 = P_7 \times P_8 \times P_9$
P_2	Customer Identification No.	2000	$5N$	$P_2 \simeq P_{10}$, $P_2 \sim P_4$
P_3	Ship to code	9	$1N$	$P_{14} \simeq P_2 \times P_3$
P_4	Salesman No.	50	$2N$	$P_2 \sim P_4 \sim P_{11}$
P_5	Model No.	150	$5A/N$	$P_5 \simeq P_{12} \times P_{13}$
P_6	Quantity ordered	—	$2N$	
P_7	Day	31	$2N$	$P_1 = P_7 \times P_8 \times P_9$
P_8	Month	12	$2A$	$P_1 = P_7 \times P_8 \times P_9$
P_9	Year	10	$2N$	$P_1 = P_7 \times P_8 \times P_9$
P_{10}	Customer N/A	2000	$50A/N$	$P_{10} \simeq P_2$
P_{11}	Warehouse name	10	$12A$	$P_4 \sim P_{11} \sim P_{15}$
P_{12}	Part No.	800	$3A/N$	$P_5 \simeq P_{12} \times P_{13}$
P_{13}	Color	20	$2A$	$P_5 \simeq P_{12} \times P_{13}$
P_{14}	Ship to address	6000	$50A/N$	$P_{14} \simeq P_2 \times P_3$
P_{15}	Pricing area	8	$1A$	$P_5 \times P_{15} \sim P_{17}$
P_{16}	Invoice No. (Shipping Notice No.)	—	$5N$	$P_{16} \simeq D_2$
P_{17}	Unit price	—	$5N$	$P_5 \times P_{15} \sim P_{17}$
P_{18}	Salesman name	50	$15A$	$P_{18} \simeq P_4$

n = number of elements in set
L = number of characters (numeric—N, alphabetic—A, or alphanumeric A/N) in each element.

TABLE 2

Document Descriptions

Shipping Notice—D1—Input

Items	Verbal Description	Information Set	Defining Relationship
D_{1-1}	Date	P_1	
D_{1-2}	Shipping Notice No.	P_{16}	
D_{1-3}	Customer Identification No.	P_2	
D_{1-4}	Ship to Code	P_3	
D_{1-5}	Salesman No.	P_4	
$[D_{1-6}$	Quantity of Order	P_6	
$D_{1-7}]$	Model No.	P_5	
D_{1-8}	Line Item		$D_{1-6,7}$

Volume: $\overline{C}D_1/P_{7E}=300$

$\overline{C}D_{1-8}/D_1=5$

Invoice—D2—Output

Items	Verbal Description	Information Set	Defining Relationship
D_{2-1}	Date	P_1	$t_E(D_2)$
D_{2-2}	Invoice No.	P_{16}	
D_{2-3}	Customer Identification No.	P_2	
D_{2-4}	Customer Name and Address	P_{10}	
D_{2-5}	Ship to Address	P_{14}	
D_{2-6}	Warehouse shipped from	P_{11}	
$[D_{2-7}$	Quantity of order	P_6	
D_{2-8}	Model No.	P_5	
D_{2-9}	Unit Price	P_{17}	$P_{17}(D_{2-8}\times P_{15})$
$D_{2-10}]$	Extended Price		$D_{2-7}\cdot D_{2-9}$
D_{2-11}	Total Price		ΣD_{2-10}
D_{2-12}	Line Item		$D_{2-7\text{ to }10}$

Producing Relationship: $D_1 \rightarrow D_2$

Operational Requirement

Volume: $\overline{C}D_2/P_{7E}=300$

Time: $t_E(D_2)-t_E(D_1)<2$ days

Customer Payment—D3—Input

Items	Verbal Description	Information Set	Defining Relationship
D_{3-1}	Date	P_1	
$[D_{3-2}$	Invoice No.	P_{16}	
$D_{3-3}]$	Amount		
D_{3-4}	Line Item		$D_{3-2,3}$

Volume: $\overline{C}D_3/D_{2E}=200$

$\overline{C}D_{3-4}/D_3=1.5$

Monthy Statement—D4—Output

Items	Verbal Description	Information Set	Defining Relationship
D_{4-1}	Customer Name and Address	P_{10}	
D_{4-2}	Date	P_1	$10/P_{8E}(D_4)/P_{9E}(D_4)$ Statements are to be dated the 10th of the month.
D_{4-3}	Customer's (old) balance		$D_{4-8}(D_{4-1},\ P_8-1)-\Sigma\ \overline{C}_{4-1}D_{3-3}(D_{4-1})$
$[D_{4-4}$	Invoice No.	P_{16}	D_{2-2}
D_{4-5}	Date of Invoice	P_1	D_{2-1}
$D_{4-6}]$	Amount of Invoice		D_{2-11}
D_{4-7}	Line Item		$D_{4-4,5,6}$
D_{4-8}	New Balance		$D_{4-3}+\Sigma\ D_{4-6}$

Producing Relationship: $P_2\times P_8\rightarrow D_4 \mid D_{4-8}\neq 0$

(statements are produced each month for each customer with a non-zero balance)

$D_2\rightarrow D_{4-7} \mid C_{4-1}\wedge C_{4-2}$

(an invoice is included in the statement if both condition C_{4-1} and C_{4-2} are true)

Special Conditions: C_{4-1}: $[P_8(D_2)=P_8(D_4)\wedge P_7(D_2)<10]\vee[P_8(D_4)-1=P_8(D_2)\wedge P_7(D_2)>10]$

(the invoice was dated after the 10th of the preceding month but before the 10th of this month.)

C_{4-2}: $\overline{\exists}D_3[D_{3-2}(D_{2-2})]$

(a payment has not been received for the invoice)

Operational Requirements:

Volume: $\overline{C}D_4/P_{8E}=500$

(the average number of statements issued per month is 500)

$\overline{C}D_{4-7}/D_4=4$

(the average number of invoices (line items) itemized per statement is 4)

Time: $10<P_{7E}(D_4)<15$

(statements are to be produced between the 10th and the 15th of the month)

(Continued on next page)

TABLE 2—*continued*

Daily Cumulative Sales Report—D5—Output

Items	Verbal Descriptions	Information Set	Defining Relationship
D_{5-1}	Date	P_1	
D_{5-2}	Salesman No.	P_4	
D_{5-3}	Salesman Name	P_{18}	
D_{5-4}	Sales this date		$\Sigma D_{5-11}(D_{5-1}, D_{5-2})$
D_{5-5}	Cumulative sales this month		$D_{5-4}+C_{5-1}\cdot D_{5-5}(D_{5-1}-1)$
D_{5-6}	Line Item		$D_{5-2,3,4,5}$
D_{5-7}	Total gross sales this date		ΣD_{5-4}

Producing Relationships: $P_1 \rightarrow D_5$
$P_4 \rightarrow D_{5-6}$

Conditions: C_{5-1}: $P_7(D_{5-1}) \neq 1$

Operational Requirements:
Volume: $\subset D_{5-6}/D_5 = 50$
Time: $t_E(D_5) - t_I(D_5) < 2$ days

TABLE 3

List of Symbols

P_i	A list of all possible information belonging to the same class
p_i	A specific member of the class
D_j	A document
d_j	A specific document belonging to the D_j class
D_{jk}	A collection of entries on the document D_j
[ ]	Line item
$\cong$	Isomorphic (one to one correspondence)
$\simeq$	Homomorphic (many to one correspondence)
$\times$	Cartesian product, e.g., $P_i \times P_k$ means a pair of p_i and p_k
$\subset$	Contained in
$\rightarrow$	Produces
E	Extrinsic time (real time)
I	Intrinsic time, e.g., date written on document
( )	Function
C_{m-n}	nth Condition relating to the mth Document
|	If
$\overline{C}_{m-n}$	Negation of C_{m-n}, i.e., $\overline{C}_{m-n}$ is true if and only C_{m-n} is false
Σ	Number of
Π	Average number of
$\exists$	There exists
$\nexists$	There does not exist

The following format is used for the information sets:

P_i	Name	Number of Items	Number of Characters (Numeric, N; Alphabetic, A; Alphanumeric, A/N)	Relationships
P_{10}	Customer name and address	2000	50 A/N	$P_{10} \simeq P_2$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
P_{18}	Salesman name	50	15A	$P_4 \simeq P_{18} \sim P_{11}$

In this problem, the customer's name is always linked with his billing address and P_{10} is simply a name for the collection of the two thousand names and addresses in the system. The fifty alphanumeric characters required represent the maximum number for any one name and address. We could, if desired, also list the mean and standard deviation, the range, or any other statistic which is applicable. The other information sets are obtained by examining all of the data flowing through the system and simply listing the sets as they are found. In this problem, there are eighteen such information sets.

RELATIONSHIPS AMONG INFORMATION SETS

One relationship that frequently exists between sets of information items is a one-to-one correspondence. Whenever there is this one-to-one correspondence between the items in one set and the items in another set, we shall, borrowing a term from abstract algebra, call this relationship isomorphism. This relationship holds, for example, between P_{10} (customers' names and addresses) and the information set that consists of customer identification numbers, P_2. That is, to each specific customer name and address corresponds exactly one customer identification number and vice versa. This relationship is read P_{10} isomorphic to ($\simeq$) P_2.

If the correspondence between the items in the information sets is many-to-one rather than one-to-one, we shall call the relationship homomorphism. For example, there are many salesmen who work out of a given warehouse, so that we may say that P_{18} (salesman name) is homomorphic to P_{11} (warehouse name). Thus given the salesman, we can find the warehouse from which he works, but not vice versa. In other words, if P_j is homomorphic to P_k then given an element of P_j we can find the corresponding element of P_k. However, unlike isomorphism, the relationship is not symmetric; given an element of P_k there is a whole set (with one or more members) of elements of P_j which correspond to it.

Since both isomorphism and homomorphism are transitive,[1] we can derive relationships which are not explicitly

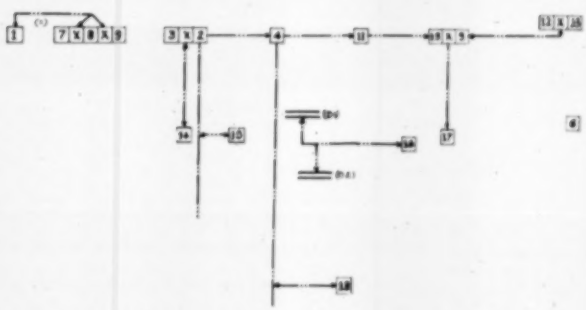

FIG. 1. Graphical Representation of Information Sets

[1] If a, b, and c are three elements and R is a relationship, then R is said to be transitive if aRb and bRc together imply aRc.

given. For example, if P_{10} (customer name and address) is homomorphic to P_{18} (salesman name) which in turn is homomorphic to P_{11} (warehouse name), we can then say P_{10} is homomorphic to P_{11}.

Our graphical notation, shown in Figure 1, provides the simplest way to derive all of the relationships among the information sets.

The double-ended arrow indicates an isomorphism between sets and the single arrow, homomorphism. The relationships hold only in the direction of the arrows so that P_{10} which is isomorphic to P_2 is also homomorphic to P_4, P_{11} and P_{15}. For convenience in drawing, the arrows can be connected to a line extending from the squares.

An item of information is sometimes the result of combining several other items; e.g., the model number is determined by the combination of part number and color, or expressed symbolically $P_5 \simeq P_{12} \times P_{13}$; this is read P_5 isomorphic to P_{12} cross P_{13}. Care must be taken to distinguish between this so-called cartesian or cross product, and arithmetic multiplication, which we always denote by $a \cdot b$ or just ab. The above says that there is a 1-to-1 relationship between the elements of P_5 and all pairs (p_{12}, p_{13}) where p_{12} is a member of P_{12} (i.e., a specific part number) and p_{13} is a member of P_{13} (i.e., a particular color).

Again the customer's actual shipping address (P_{14}) (store, warehouse, etc.) is determined by the combination of his identification number (P_2) and the ship-to code, i.e. $P_{14} \simeq P_2 \times P_3$.

In the case of date (P_1), we say that P_1 is equal to (rather than isomorphic to) $P_7 \times P_8 \times P_9$ (day, month and year) since an element of P_1 actually consists of the day, month and year taken from P_7, P_8 and P_9. Since certain triplets of day, month and year do not exist, it would be more correct to say that P_1 is contained in (symbolized by $\subset$) $P_7 \times P_8 \times P_9$. Operationally, however, this should be no problem since dates such as Feb. 31, 1958 should not enter the system.

P_{16}, the information set consisting of invoice numbers and shipping notice numbers (in this problem the same number is used for both) must be handled in a slightly different manner. Since these numbers are created at the same time as the documents they identify, they bear a definite relationship to these documents. In fact, there is a one-to-one correspondence between the numbers and the documents so that we may say that

$$P_{16} \simeq D_2$$
$$\text{and } P_{16} \simeq D_1$$

This implies a relationship between P_{16} and any of the information sets to which the items on the document belong, viz:

$$P_{16} \frown P_j$$

where P_j is any information set to which an item on the document belongs. In other words, given an invoice number we can find the specific entries on the document.

The following format is used for the documents:

Name of Document		Number (D_j)		Input, Output
Items	Verbal Description	Information Set		Defining Relationship
.	.	.		.
.	.	.		.
.	.	.		.
D_{jk}	—	P_i		—

Producing Relationships:
Special Conditions:
Operational Requirements
Volume:
Time:

For each document we record its name, number and whether it is an input or output document. The items D_{jk} are entered along with their verbal description, the information set to which they belong, and, for output documents, the defining relationship, which tells from where the item is taken or how it is derived. If no relationship is shown, the item is derived directly or indirectly from the producing document. Whatever producing relationships and special conditions apply are listed at the bottom together with the volume and time requirements.

One characteristic of a document is that it contains not only information that appears only once but also information, known as line items, which may be repeated any number of times. The line item for the shipping notice (D_1) is $D_{1\text{-}6}$ and $D_{1\text{-}7}$, quantity ordered and model number, and is distinguished by placing square brackets around it. A particular shipment may consist of 7 different models so that the line item would be repeated seven times, each containing a different quantity ordered and model number. In order to refer to a line item as a whole, without the necessity of repeating its elements, an item, $D_{1\text{-}8}$, is added and used whenever reference is made to an operation which pertains to each of the line items. For convenience, the items contained in a line item are listed in the defining relationship column. Thus $D_{1\text{-}8}$ is shown to consist of $D_{1\text{-}6}$ and $D_{1\text{-}7}$.

We distinguish between two kinds of time, extrinsic or E time and intrinsic or I time. Extrinsic time is the time at which an event occurs, e.g., the production of an output document, and intrinsic time is the time which is an information item on a document, e.g., the date written on the document.

Using this symbolism we can now express elapsed time relationships. For example, if the invoice must be produced within two days after the receipt of the shipping notice by the system, we would write:

$$t_E(D_2) - t_E(D_1) < 2 \text{ days.}$$

Absolute instead of relative time can also be expressed, e.g.

$$10 < P_7[t_E(D_4)] < 15$$

implying that the day (P_7) of production of D_4 must be between the 10th and 15th (of the month). Expressions of this kind will often be condensed from $P_7[t_E(D_4)]$ to

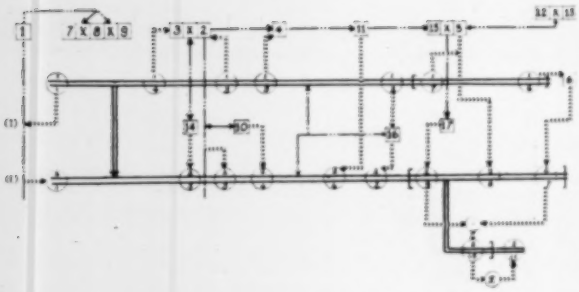

FIG. 2. Graphical Representation on D_1, Shipping Notice and D_2, Invoice

just $P_{7E}(D_4)$, since P_7 is an information set consisting of time units. We can apply arithmetic operations to dates as in the specification of D_{5-5} in Table 2 where D_{5-5} $[(D_{5-1}) - 1]$ means that we take D_{5-1} (date), subtract 1 from it, and look up D_{5-5} from the D_5 with this date.

The volume statements on the shipping notice state that the average number (indicated by the square C with the bar over it) of shipping notices (D_1) per day (P_{7E}) is 300 and the average number of line items (D_{1-8}) per shipping notice is 5. The special symbols are used with an eye toward future automatic programming input.

A graphical representation of the shipping notice and the invoice together with the information sets is shown in Figure 2.

The items on a document are connected by a (generally horizontal) double line and the item numbers are entered in a circle. By convention the circles on input documents are connected to their corresponding information sets by a line with an arrow pointing toward the information set. The line items are enclosed by square brackets. The graphical representation makes it easy to pick up redundant information. For example, D_{1-3} is a member of P_2 which in turn is homomorphic to $P_4 \cdot D_{1-5}$, which is a member of P_4, could therefore be derived from D_{1-3} by a table look-up. In other words, it was not necessary to input the salesman's number as it could have been derived from a knowledge of the customer number. Note also that it was not necessary to know what meaning was given to D_{1-3}, D_{1-5}, P_2, and P_4 in order to determine this redundancy.

PRODUCING RELATIONSHIPS

We have discussed certain relationships among the information sets; other kinds of relationship may exist among documents, and between documents and information sets. One of these relationships is that of "produces." In general, a document will be produced in one of two ways:

1. Periodically, once every day, week, etc.
2. Irregularly, once for each occurrence of an input document or of a condition dependent on input data.

For example, since an invoice (D_2) is created for every shipping notice (D_1) that is received, we say that

$$D_1 \rightarrow D_2 \text{ (read } D_1 \text{ produces } D_2\text{)}$$

The producing relationship is concerned with the existence rather than the content of the document involved. The daily sales report is produced each day, so the date produces the report; however, this does not tell us what is on the sales report or from where its information is taken. In general, though, the items on an output document will be derived from the document which produced it, unless the defining relationship specifies some other way to derive these items.

DEFINING RELATIONSHIPS

The defining relationship tells us the content of the output items. The exact specification of how this content is to be generated is left to the subsequent mechanization of the problem. Where no defining relationship is given, it is understood that the items are to be copied or derived from the input document that produces the output. These items are copied directly from the input when both input and output items belong to the same information set. They are derived indirectly from the input when the input and output items belong to different but related information sets. For example, the customer name and address (D_{2-4}) on the invoice (D_2) belongs to P_{10} (the information set consisting of customer names and addresses). No defining relationship is given opposite D_{2-4} in Table 2; thus for the derivation of D_{2-4} we must look to the input document (D_1) which produces D_2. However, since no item in D_1 is a member of P_{10} (that is, the customer name and address does not appear on the shipping notice), we must find some item on D_1 whose information set is related to P_{10}. Referring to Figure 1, we note that P_2 is isomorphic to P_{10} and that D_{1-3} is a member of P_2. Thus we know that D_{2-4} can be derived from D_{1-3} via the relationship between P_{10} and P_2. In other words, given the customer identification number on an invoice we can find the customer name and address for the corresponding invoice. Note that nothing need be said as to how this is done. It may be desirable to maintain a file within the system and find the customer's names by a table look-up or this may be done manually

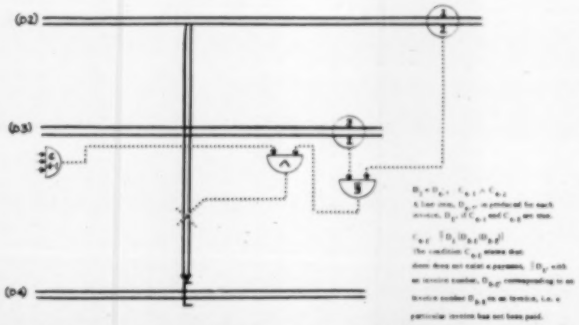

FIG. 3. Graphical Notation of a Conditional Relationship

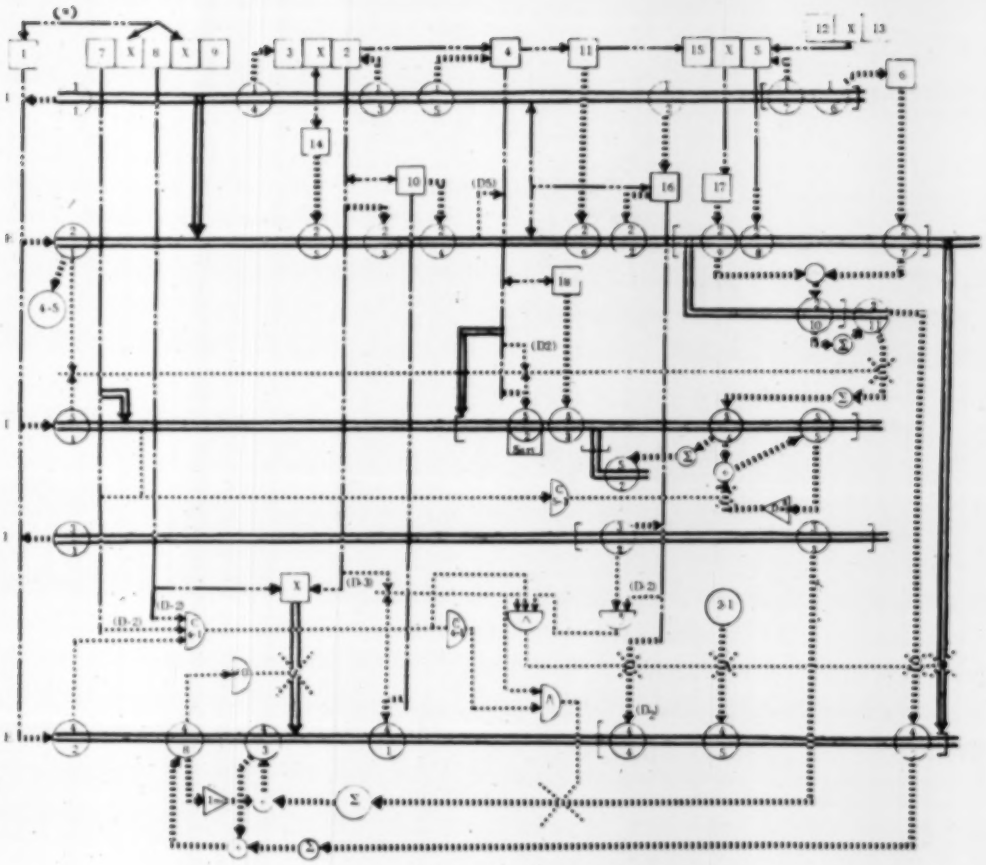

FIG. 4. Complete Graphical Representation

outside of the system. We have merely stated the requirement that it be done.

One way of symbolizing that an item in one information set is to be derived from an item in another set is by means of the function notation of mathematics. For example, the unit price depends upon both the model number and the pricing area in which the item is sold so that $D_{2\text{-}9}$, the unit price, (which belongs to P_{17}) is specified in Table 2 as $P_{17}(D_{2\text{-}8} \times P_{15})$. This is read as P_{17} of $D_{2\text{-}8}$ cross P_{15}, and means that the system is to look at the combination of a model number ($D_{2\text{-}8}$) and a particular pricing area (belonging to P_{15}) and put the corresponding member of P_{17} (unit price) in the space designated as $D_{2\text{-}9}$ on the invoice.

Note that the pricing area (P_{15}) may be derived in a number of ways, e.g., from a member of P_{11} (via $P_{11} - P_{15}$), from a member of P_4 (via $P_4 - P_{15}$), or from a member of P_2 (via $P_2 \sim P_{15}$). That is, the pricing area can be found from either the warehouse name, the customer identification number, or the salesman number. Again, the particular choice of deriving the pricing area is left to the subsequent mechanization of the problem.

The defining relationship may be a simple mathematical relationship between various items, e.g., the extended price ($D_{2\text{-}10}$) is found by multiplying the quantity ordered ($D_{2\text{-}7}$) by the unit price ($D_{2\text{-}9}$). Thus, $D_{2\text{-}10}$ is defined as $D_{2\text{-}7} \cdot D_{2\text{-}9}$ (read $D_{2\text{-}7}$ times $D_{2\text{-}9}$). In the graphical notation, Figure 2, this is indicated by drawing information flow lines from $D_{2\text{-}7}$ and $D_{2\text{-}9}$ to a small circle which contains the arithmetic operation to be performed. The output of this operation is then shown going to $D_{2\text{-}10}$. The fact that D_1 produces D_2 is shown by the vertical double line with the arrow pointing from D_1 to D_2.

The defining relationships may become very complex. They may contain conditional statements or may involve arithmetic operations on time units.

CONDITIONS

Decision making is another important part of any data processing problem; here we have available the help of symbolic logic (1). For example, the condition $C_{4\text{-}1}$, the first condition on the fourth document, is of the form (p and q) or (r and s) where p, q, r, and s are equalities or inequalities on certain dates; $\wedge$ is used for "and," and "$\vee$" for "or." This condition states that the invoice was dated after the 10th of the preceding month but before

the 10th of this month. C_{4-2} is written as:

$$[P_8(D_2) = P_8(D_4) \wedge P_7(D_1) < 10] \vee [P_8(D_4) - 1 = P_8(D_2) \wedge P_7(D_2) > 10]$$

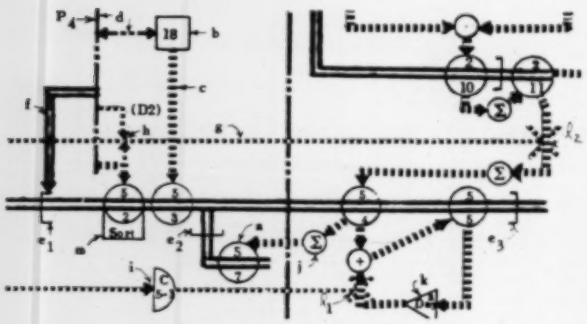

FIG. 5. Explanation of Graphical Notation

EXPLANATION OF GRAPHICAL NOTATION (FIGURE 5)

a. This circle represents an information item on a document, viz., D_{5-7}, with the document number above the line, and the item number within the document, below. The heavy double line (generally horizontal and possibly with branches) connects all the items on one document.

b. Each information set, P_i, is shown as a square, in this case P_{18}.

c. An item on a document which is an element of some P_i is connected to it; the arrow runs out of the document for an input, into it for an output (i.e., one may think of the flow of information to and from the system as following the arrows).

d. Isomorphism (or homomorphism) between information sets is shown by a double (or single) headed arrow. In this case we are saying that $P_{18} \simeq P_4$, with the square standing for P_4 having been extended downward by the broken vertical line.

e. The small square brackets enclose those items making up a line item of a document, in this case $D_{5-2,\ 3,\ 4\ and\ 5}$. Note that D_{5-7} is not a line item and is excluded by the bracket e_2.

f. The producing relationship is shown by a double heavy line with an arrow pointing to the document or line item produced, e.g., P_4 produces a line item on D_5. The line runs from the extension (the vertical broken line) of the square box representing P_4 to the bracket representing a line item on D_5.

g. The dotted line is used to connect various elements of a condition.

h. The condition at h is that D_{5-2} is equal to P_4 (D_2), represented by condition lines from D_{5-2} and P_4 with arrows to the condition line g. That D_2 is involved is shown by writing in (D_2).

i. This is the standard symbol for a gate and states the condition involved, viz., C_{5-1}. The input to the gate (the flat surface) is connected to the item or items involved in the condition. The output goes to the operation affected by the condition.

j. The summation sign indicates that D_{5-7} is equal to the sum of D_{5-4}.

k. The triangle represents a delay equal to the time indicated within it. Thus yesterday's D_{5-8} is added to D_{5-4} to produce today's D_{5-5}.

l_1 & l_2. The dotted cross through an information transfer line (l_1) or a sum (l_2) (or any other operation or production) indicates that this transfer or operation is performed if the condition is true.

m. The sort notation implies that the document or line item must be sorted by the item indicated.

A bar over a condition indicates the negation of that condition, i.e., $\overline{C}_{m-n}$ is true (or false) if C_{m-n} is false (or true). The statement in a defining relationship of a calculation involving a condition is often simplified by interpreting C_{m-n} as a number which is 1 if the condition is true and 0 if it is false. For example, one entry on the monthly statement (D_4) is the customer's old balance (D_{4-3}). This is defined as last month's new balance for this customer minus payments against invoices dated prior to the period covered by this statement. D_{4-3} is then defined as:

$$D_{4-3}\ (D_{4-1},\ P_8 - 1) - \Sigma\ \overline{C}_{4-1}\ D_{3-3}\ (D_{4-1})$$

Thus the system is to find the new balance, D_{4-3}, on last month's, $P_8 - 1$, statement for this customer, D_{4-1}, and subtract from it the sum of this customer's payments, D_{3-3} (D_{4-1}) which do not meet the condition that the payments were made during the time period covered by this statement, $\overline{C}_{4-1}$, where C_{4-1} is the condition which specified the period.

The second condition, C_{4-2}, on the monthly statement states that a payment has not been received for the invoice; here "$\exists$" is used for "there exists" and "$\nexists$" for "there does not exist" so that $C_{4-2}, \nexists\ D_3[D_{3-2}(D_{2-2})]$, implies that the system started with D_{2-2}, and invoice number, and found that there did not exist in the system a customer payment, D_3, with the same invoice number (D_{3-2}).

Conditional statements may be involved in the producing relationship. In describing the conditions to be met before some action is taken, we use a vertical line to symbolize "if," e.g., in saying

$$D_2 \rightarrow D_{4-7} \mid C_{4-1} \wedge C_{4-2}$$

or an invoice (D_2) produces a line item on the statement (D_{4-7}), if C_{4-1} and C_{4-2} are true.

Figure 3 illustrates this producing relationship. D_2 is shown producing the line item D_{4-7} by having the producing arrow run to the square bracket indicating the line item. The condition on the producing relationship is indicated by the X on the producing line leading to a gate. The input to this gate are the conditions C_{4-1} and C_{4-2}. The condition C_{4-2} is diagrammed completely showing that the input to the gate containing the "there does not exist" symbol is D_{3-2} and D_{2-2}.

If the condition is simple it may follow the vertical line itself as in

$$P_{10} \times P_8 \rightarrow D_4 \mid D_{4-8} \neq 0$$

or a statement, D_4, is produced each month (P_8) for every customer (P_{10}) who has an open balance $(D_{4-8} \neq 0)$.

CONCLUSIONS

We have shown how a simplified problem can be stated in pseudomathematical terms. Such a tool has many advantages for a systems analyst. In reviewing an existing problem it provides the ability to insure that all of the input entries are used to produce outputs. By presenting

all of the alternative methods of deriving information, it facilitates making decisions on the best organization of the inputs. It also helps in determining the cost of producing outputs, one criterion for their inclusion. For programming purposes, it provides an unambiguous statement of the problem to the programmer. The maximum number of files, record lengths, file densities, volumes, amount and type of computation required, etc., can be easily determined. The graphical presentation, which can be modified to suit the needs of the user (e.g., by including descriptive labels), should be helpful in determining the best organization of files and subroutines and in providing a check on redundant and superfluous information.

At first glance it may seem that we have made the problem statement more, rather than less, complicated. However, the statement of a problem in these terms clearly cannot be more complex than the problem itself. The cost of current data processing no longer permits incomplete or partial solutions, and ultimately, we would like the computer to solve the problem of its own best use. The first step toward this goal must be a statement of the problem which the computer can understand.

REFERENCE:

(1) Ackerman, S. A., "Symbolic Logic," *Journal of Industrial Engineering*, Vol. 8, No. 5, 1957, pp. 293-299.

Trade Unions and the Philosophy of Wage Incentive Systems

by **NORMAN KOBERT**

Assistant Director, Management Center, Marquette University

IN ORDER to understand the attitudes of unions towards wage incentive plans, an understanding of the ramifications of wage incentives and unionism's effect on wages must first be derived. This understanding helps, then, to place the union attitude in proper perspective.

A proper study must also not only include yesterday's history and today's events, but must also account for tomorrow's variations from existing patterns. No one can feel complacent in the acceptance of today's attitudes as the end of the evolutionary process of labor-management relations, even though this past century has seen the growth of unionism to such a degree that collective bargaining can now be termed a more equal bout with more or less evenly matched opponents. The march of tomorrow's events could alter this arrangement quite perceptively, and may very well herald the advent of stronger third parties in the form of governmental action and public opinion.

The development of our society, both economic and social, is also necessary to be understood. When we work in a society as described by Veblen's concept of "Efficient Production," we must think in terms of the need for more goods and therefore a society of production. Percival and Paul Goodman, in their study, "Communitas," visualize a society of consumption, where production is only a means to the end of consumption and therefore satisfaction in the work disappears. The workman accordingly focuses all his demands upon suitable work conditions, short hours, and high wages, so that he may hasten away with sufficient time, wealth and energy to seek the goals of the consumer. Most societies tend to fall short of their Utopias, so that we must perform our studies against the backdrop of our mixed production-consumption society.

A further problem which must be considered is the relationship of our knowledge of individual motivation to a generalized statement which would include and represent the motivations of a large laboring group. Professors Thomas Ryan and Patricia Smith have stated this much more succinctly (15, p. 353):

> . . . the solution of the special problems of industrial motivation will be only a partial one until a satisfactory approach to motivation in general has been worked out. The motivation of work cannot, therefore, be considered independently of other problems of motivation, and the industrial psychologist must . . . search for an adequate general theory of the initiation and control of activity.

These then are some of the background considerations in the analysis of union attitude towards wage incentive systems.

WAGE INCENTIVES AND WAGE INCENTIVE PLANS

The basic principle behind the payment of additional wages for additional productivity lies in the fact that one of the factors of worker motivation is pay. In the past, monetary remuneration was thought to be the major motivation for having work performed. Many studies, from the late 1940's on, have shown that monetary compensation, although not a major motivation, is, at the very least, one of the top five reasons why men work.

The history of wage incentives dates back as far as it can be shown there existed an agreement to pay an employee for the amount of work produced. In this country, the earliest use of wage incentives would involve a long

look at the home-work system of spinning and weaving yarn and fabric. These early systems however are not comparable to present day plans, because in those days the employer was not interested in productivity, but rather in goods or services of a specified quality being delivered at a set price within a reasonable period of time.

It is with the development of the centering of the productive processes "under one roof," the factory, that we now associate incentive systems. Employers now were interested in spreading overhead by increasing output. The fear by labor of rate cutting was prevalent. This fear, well founded in many cases, led to restricted production in our newly formed factories.

The wage incentive systems developed around the turn of the century were aimed at alleviating this drawback. These took into account two developments, 1. the introduction of systems wherein both employer and employee shared the savings in direct labor costs resulting from increased production and, 2. the development of methods of setting performance standards, namely, time study. Various forms of profit sharing plans and the use of nonfinancial incentives were also recommended as solutions to the problem of rate cutting and restriction of output, but these are outside the scope of the present discussion.

Many types of earning arrangements had been tried in Europe long before these present plans were "reinvented" in the United States. Alford and Bangs stated, "European plans were never very successful, however, because they were applied to either guessed or bargained standards of production." The techniques of methods improvement and work measurement, as developed in the U.S. by Frederick Winslow Taylor and his associates, made such plans successful, and consequently engineers of this country have been given the whole credit for their origination (2, p. 1173).

Many plans were devised from 1890 on, most of this synthesis occurring prior to 1925. The greatest impetus to the development of wage incentive plans was given by the proponents of "scientific management" and their successors, the "efficiency experts" of the 1920's. It was these men who pushed for wage incentives as a management tool to reduce costs and emphasized. 1. the role of wage incentives in motivating workers to increase their rate of output and 2. the role of wage incentives in stimulating management to be more efficient in performing its functions (20, p. 8). It might be said that the opening gun in this campaign was fired in 1895 when Taylor's original epoch-making paper, "A Piece-Rate System," was published (18, p. 856). He said,

> Since under this system, the rate-fixing is done from accurate knowledge instead of more or less by guess-work, the motive for holding back on work, for "soldiering" and endeavoring to deceive the employer as to the time required to do the work, is entirely removed, and with it the greatest cause for hard feelings and war between the management and the men.

We shall examine this statement made 60 years ago as we proceed.

PHILOSOPHY OF WAGE INCENTIVES

As stated before, the origin of the use of wage incentives has been management's desire to increase productivity with approximately the same investment in plant, equipment, supervision, etc. However, this philosophy must be expanded to include the motivations and the rewards for the workers.

Wolf reduces this to simple syllogistic form, holding (20, p. 73):

1. That workers work for monetary rewards.
2. That for additional remuneration, workers will increase output.
3 That, therefore, a system of pay that automatically ties earnings to output increases production.

Modification of this logic would involve the introduction of data relating to other motivations which are more primary than the drive for pecuniary reward. It is true, however, that people obtain the means of satisfying their wants and needs by selling productive power to industrial establishments.

As Chandler points out, in our society money is the principal medium of exchange and, the main standard and store of value, among other things (5, p. 9). It not only provides a means of control over material things, but it also has intrinsic value as a symbol of status and security. Therefore, its place in the listing of primary motives for producing work should not be taken lightly.

Wage incentives also appeal to those philosophical enough to consider the precepts of our capitalistic, free enterprise system. These precepts include 1. that laboring personnel should be remunerated in accordance with their worth as productive members of our society and 2. that the individual should be able to seek his own level of effort. Therefore, by rewarding extra effort and by increasing the relative ability of the worker to better his position, wage incentives conform to these basic values.

This understanding of the appeals and logic of wage incentives is important to an understanding of the reasoning and appeals of unionism in situations involving monetary incentives.

SCOPE OF WAGE INCENTIVES

In order to understand the range and magnitude of this study, it is essential to determine the extent to which incentives have become a major payroll-productivity factor.

Some of the most reliable data, not based on sampling alone and well-detailed, are contained in a survey by the National Industrial Conference Board (24). Although this study is a bit dated, it is still referred to by current writers. This survey of 2,700 companies, representing all kinds and sizes of businesses in the U.S., showed that 51.7% used wage incentives, or 2,655,000 out of 5,000,000 workers in these companies. Of the 900 manufacturing companies, ranging in size from 100 to 10,000 workers, 75% used wage incentives. It was also apparent from

this study that company size made no material difference as to the use of incentives.

It should be pointed out that the Department of Labor and National Service stated in 1950 that about 30% of manual workers in manufacturing industry received incentive payments (23).

In 1943, the American Management Association made a sampling survey of 50 representative manufacturing companies. This showed that 62% of direct producers and 17% of indirect producers were being paid extra-financial incentives. There was an equal division between those paying individual incentives and those paying group incentives. The study concluded that incentives generally increased production but that technological and other changes made this difficult to measure.

It is clear, incentive workers are not a small minority.

WAGES, INCENTIVES, AND UNIONISM

Labor unions have varied in their ideologies, leadership, membership, environment, political leanings, etc.; but, if one factor can be universal concerning them, it is their unified drive for more pay for their members. The more profound economists state this as a promise to redistribute the national income, at the very least in favor of their members, and at the most in favor of the total working population.

Nevertheless, labor's share of national income has remained more nearly constant than almost any other economic variable in society. J. M. Keynes, the noted economist thought this stability was "a bit of a miracle" (10). If Keynes and the statistics are right, Clark Kerr says, the world has seldom seen so much expenditure of effort, emotion and invective with so little result (9, p. 2).

This phenomenon is not purely local in nature. Australia and England have both perceived the same situation as existing when comparing labor's rising income with respect to the gross national income and the relative price index. In Australia for example, the Commonwealth Conciliation and Arbitration Act has been in effect since 1904. This act provides for compulsory collective bargaining regulated by tribunals created to preserve the King's Peace and to protect the community interests. Yet, in the fifty years of compulsory collective bargaining, with all the stresses and pulls of the rapidly expanding Australian economy, money wages 1913-1948 almost trebled while real wages rose only by 36% and the wage earner maintained the same percentage of the national income when compared to entrepreneurial income, property income and pension income, in fact this percentage fell by 10% shortly after World War 2 (19, p. 326).

Real hourly wages in the United States doubled between 1914 and 1939 (28) and in Britain real hourly wages rose by approximately 50% (4, p. 30). Hours of work in the U.S. fell by 29% between 1909 and 1939, compared with the fall of 18% in Australia and 10% in the United Kingdom.

The principal factor responsible for these different rates of improvement in wages and hours appears to be the variation in the rate at which productivity has risen in the countries concerned. For the most part, rises in real wages matched increases in productivity. In the U.S., for example, where real hourly wages doubled between 1914 and 1939, productivity per man-hour also doubled (28) and in Britain, where real hourly wages rose by about 50%, productivity per man-hour increased by the same proportion.

This close correspondence of changes in real wages to changes in productivity in countries of widely different economies and industrial relations suggests that the power of unions, to effect a change in the percentage share of a nation's increasing income through increased productivity, is negligible. Although they have not exercised a decisive influence on the general level of real wages, unions have probably played a part in insuring that the general level of real wages has not lagged unduly behind productivity. This has been mainly due to worldwide union emphasis on shorter hours for the same pay.

It is significant to reemphasize the point previously mentioned, that about 60% of the U.S. production workers were participating in wage incentive plans. In Australia, in Sept. 1949, 32% of the workers received incentives, 17% of this total were manual workers in manufacturing industries on piece-work or bonus payments based directly on output (8). In Britain in April 1947, 26% of manual workers were being paid under a system of payment by results.

It is also significant that in Australia, the unions have fought determinedly against the extension of wage incentives. In the furniture industry, for example, the union's strong opposition to systems of payment by results might appear inconsistent with its attitude towards technological change (19, p. 59). Technological change has been acceptable to the union because its basic tendency is to make the "back-yard" businesses unprofitable. In the case of payment by results, however, the traditional opposition of the craft groups was not so readily overcome.

Although it might be true that payment by results would reduce overhead costs and have the same effect on "back-yard" competition as technological progress, the result was evidently to be achieved by greater effort on the part of employees, and the dominant impression was one of a direct threat to the security of all employees, skilled and unskilled, by speed-up and possible overproduction. Technological progress, in contrast, offers the immediate prospect of cost reduction at the existing output, and does not raise the possibility of overproduction so directly.

As was pointed out previously, some of these same arguments were raised by American unionism at the turn of the century. The main union objections today in America shall be discussed a bit later, but it is significant that these revolve about two other points entirely. Their objections are, briefly,

1. Incentive pay, with rates set by different standards in in-

dividual factories, even in the same industry, strike at the heart of the drives for uniformity of wage standards. Further differential is caused by varying worker productivities on similar or identical jobs.

2. The methods of measuring work through the establishment of time studied standards has been and remains a bone of contention between labor and management.

WAGE INCENTIVES AND MANUFACTURING COSTS

The theory behind management's use of wage incentives is based on the assumption that increased output of product within the same plant, with the same equipment and approximately the same amount of supervision and other indirect services, lowers unit costs. This means that many costs, which ultimately determine selling price, do not increase proportionately with increases in the workers' productivity. Further, an increase in the rate of output per worker brings about a reduction in the marginal cost of each incremental increase in output.

To cite an example: If management was paying $20 per day for 2000 units of production under a time wage system of payment, this means they were willing to pay one cent per unit and were still in business making a profit. Let us further assume that overhead costs amounted to $30, or one and one half cents per piece; a total of 2½ cents for all costs per unit.

If under an incentive system, assuming a base wage of $20 is guaranteed to all direct employees, management now is willing to pay one cent (or even 1¼ cent) per unit in direct pay for production over and above 2000 units, this means the average incentive worker can earn between $22 and $26 for 110% to 130% pace. This gain in productivity per worker is obtained at the cost of running an incentive system, while the cost per unit for equipment, supervision, plant, etc. decreases markedly. At paces of 110% to 130% of base total costs may drop from 2⅓ cents to 2$\frac{1}{10}$ cents per unit (plus the additional cost per unit of administering the new system).

Another point with regard to the relationship of wage incentives and manufacturing costs deals with work scheduling. The complexity of modern manufacturing establishments requires the determination of a vast number of component and sub-assembly production and procurement sub-schedules, which are subordinate to a master plan or schedule involving final assembly, inspection, packaging, warehousing and shipment.

Schedules are usually no better than the information available upon which they are based. One of the prime pieces of information needed is "how long" should the job take. This may be derived from time studies standards, past history or the best guess of a technically competent individual.

In incentive plants one must take into account the pace over and above the standard pace at which incentive employees work. A shortening of the amount of time necessary to complete components may lead to a reduction in cost of "in-process" inventory as well as raw material inventory. This becomes evident when one considers that inventory is a cost from the time raw material is paid for to the time when the finished products are sold.

A further advantage lies in the ability to devise more flexible schedules when dealing with briefer manual time sequences and machine loading times. This relates to the scheduler's placement of jobs to be done to achieve the minimum amount of hours for equivalent work to be produced. In mathematical programming this would be equivalent to increasing the variety of methods of handling the variables of production in order to minimize the hours required.

This chapter of the study is intended to demonstrate management's motivation for adopting a wage incentive system. Obviously benefits accrue to labor as well, but there is very little evidence to support any claim to the establishment of any wage incentive system by a labor or union group. Not to be overlooked, however, is the very active participation and interest shown by labor in the initiation, extension and continuance of these systems subsequent to any original pronouncement by management that indicates an intention of establishing such a system. It is for this reason that, in my opinion, wage incentive plans can be thought of as management plans; their success, however, dependent upon worker motivation and union attitude.

WAGE INCENTIVES AND INCREASED PRODUCTIVITY

The gains to management, being dependent on increased productivity by labor, must therefore relate to wage incentives as a motivating force. Likewise, the assumption of wage incentives as a motivating factor should make increased productivity evident in those plants where such systems have been adopted.

In a study of machinery manufacture, cotton-textile manufacture and the primary fabrication of nonferrous metals, the Bureau of Labor Statistics (27) compared the hourly earnings of time workers with those of incentive workers in identical operations in these industries. The report stated,

> . . . a definite and substantial margin in favor of the workers paid under incentive plans. . . . Incentive workers were earning, per hour, between 10 and 20% more than the time workers. Differences of less than 5% or more than 30% were but rarely encountered. . . .

A later study, based on a survey of 34,000 manufacturing establishments, concerning about five and one-half million workers, and 21,000 plants concerning one and one-half million workers, concluded (16):

> Generally, incentive workers receive higher earnings than do time workers in comparable jobs, although the size of differential is not consistent from industry to industry. The earnings advantage of incentive workers ranged from less than 5% to at least 40% in the individual manufacturing industries . . . ; in many of the industries the difference was between 15 and 25%.

This report went on to compare the differential in pay,

industry by industry, for example:

Apparel	20–40%
Metal Working	20–25%
Textile	10–16%
Chemical	slight
Non-manufacturing (includes dept. stores, garages, etc.)	30%

The U.S. War Production Board's Management Consultant Division in 1944 investigated eighty-six wage incentive installations in the Chicago area and found that, on the average, worker's earning under incentive increased by 19% (29). Similar results in various other surveys have shown this increase over 100% base productivity to average 24.4%, 20% and so on.

The Dartnell Corporation, in a study of 117 companies in 1948 concluded that the range of incentive bonuses was between 5 and 55% with the average around 25% over the base pay (22).

It is important to note the discussion of *average*, because, if a plant averages 125%, we can expect a modal value at that point when plotting percentage bonus vs number of employees receiving bonus. This means that approximately one-half of the employees will receive less and one-half more than this modal average. The surveys indicated above took the average of an industry's or area's averages as their indicator. If we realize that for each individual average there is a range of employees below and above this value, we can derive a better understanding of the effect of wage incentives on American industry.

Ralph Barnes (3) and Ralph Presgrave (14) suggested that the ratio between the best and the worst operators varies between 1 to 2 and 1 to 2.5. Between the best and the worst operators on incentive there might exist a range of between 80 and 160% of base rate when the average pace is approximately 120-125%. The distribution of the frequency of occurrence of various paces about the average would follow the pattern of a normal frequency distribution curve (7).

Mundel stated (12, p. 309),

> The nature of the distribution of capacities is such that with each trait the greater number of people tend to possess an average amount, with the number diminishing as the extremes are approached . . . well-performed worker selection, pacing by limits of equipment, and group work will tend to reduce the spread of the [normal curve].

This dispersion analysis becomes increasingly important when we discuss one of the two major objections by unions to wage incentives. As was stated before, one of the major objections was:

> Incentive pay causes differentials in pay between workers performing identical or similar jobs in the same industry, plant and even department of a plant.

INCENTIVES AND WAGE STRUCTURES

There is every indication to show that the use of a system of payment by results injects a dynamic element into the wage structure. This becomes evident as traditional wage differentials are upset and along with them the traditional evaluations built up in the workers' minds. The problem is usually accentuated in those cases where, to the employee, these changes appear to be illogical and unreasonable.

Wolf stated that this distortion is inherent in the use of systems of payment by result and arises from (20, p. 128):

1. Differences in potential earnings on different jobs.
2. Differences in ability among workers on the same job.
3. Differences in the ability of a specific worker on different jobs.
4. Differences in the pressures that groups of workers may apply for loosening up standards of output.

These differences are not so apparent in a day work plant, because, although everyone is at least expected to meet some minimum of production, there is no motivation to exceed this minimum. Therefore, a frequency curve would never approach a "normal" shape and we might expect a very narrow range of dispersion about the minimum expectable level of productivity.

If extra pay is paid for extra effort, variations in pay will indicate the superior, average and sub-average operator. This categorizing is most important to management as a device for focusing attention on worker performance, thus making the immediate supervisor's job a bit less based on opinion and a bit more based on fact. Wage incentives may bring to light worker deficiencies that will point the way to positive programs of training, selection and placement.

Now, what of the union? Prior to wage incentives, the primary drives by unions were for more pay, shorter hours and better working conditions. The use of wage incentives has focused attention on the "slackers" and on the latent productivity that is inherent in all plants on a time wage payment basis. To combat this "hot potato" thrown in their laps, many unions have reacted in different ways. Some, like the International Ladies' Garment Workers and the International Brotherhood of Machinists, formed their own Industrial Engineering departments. Some locals refused to allow incentives as a means of payment. Some attacked the right of management to determine standards, while others accepted this right by management, as long as the method of setting the standard could be reviewed and could be bargained.

William Gomberg, former Director of Management Engineering of the ILGWU, stated unequivocably, "The question of labor's participation in the setting of production standards is now pretty well settled" (6, p. 35). He points to the arbitration award settling the strike against an alleged speed-up of the Ford production workers in the River Rouge plant. The contract between Ford and the then UAW-CIO at that time specifically gave management the unilateral right to determine production standards. The arbitration award recognized "the right of the company to establish and determine and to main-

tain and enforce standards of production." With regard to the number and location of plants, products to be manufactured or schedules of production, this right was held to be inviolate. Such was not the case with respect to production standards. There this right meant only to initiate, and therefore upheld the union demand to question the company's standards. A more recent case upholding this point was J. I. Case Co. and UAW, AFL-CIO, July 11, 1957.

On the other hand, there are many companies today whose management is of the definite belief that standards are not subjects for arbitration the way wages and hours are. J. K. Louden stated, ". . . a standard must be based only upon facts and changed only by facts" (11, p. 161). The reasoning behind this position is that standards must not be subjected to negotiation or arbitration either in their establishment or in their change.

In order for management to take so firm a stand, it is clear that they must "come into court with clean hands." The system for establishing performance standards must be so devised and objective to be above question by those who must operate under it. So, once again the "hot potato" has been tossed, this time in the lap of management. As much as wage incentives have shown up the "featherbedding" of employees, so has it placed management in the position of defending its time standards.

One point is clear, no one can smugly assume the pendulum will not return, for the automated factory will lead to mechanical pacing of any manual labor attendant to it.

THE PERFORMANCE STANDARD

As was stated previously, the second main objection of unions to the use of wage incentives was in the present methods of work measurement.

Frederick W. Taylor, called by many the father of time study, stated (25, p. 40):

> Time and motion study are the accurate scientific methods by which the great mass of laws governing the best, easiest and most productive movements of men are investigated. They substitute exact knowledge for prejudiced opinion and force in determining all the conditions of work and pay. . . . As reasonably might we insist on bargaining about the time and place of the rising and the setting sun . . . [as bargain over the results of time and motion study].

Would that this could be true! Not even those proponents of the "exact" sciences would dare make so precise a claim for their profession. No designer of structures would ever complete his multitude of calculations re yield points in tension, rivet shear capabilities, girder compression strengths, etc. and then not add a "safety factor" of 5 or more. As precise as his calculations are, this addition of a factor of safety adds 500% or more to the cost of steel needed for the given structure.

No one in their right mind today would make a statement like Taylor's, considering not only the variations of given formulae when applied to steel, or any part of our material world, but any law which relates to the human being and all his inherent variations.

Of all of the elements of establishing a standard, the most controversial portion of time study has been the rating, normalizing, or leveling procedure. Very much less argument exists today concerning:

1. The selection of the operator to be studied.
2. The job description and the elemental breakdown of the job.
3. The pace or conditions under which the job is to be studied.
4. The type of recording instrument.
5. Snap-back vs continuous watch reading.
6. The collection and computation of the data necessary to pay incentive wages for incentive pace.

One other element of time study not listed above is the calculation of the amount of personal and unavoidable delays which occur during production time. This however, is a problem which differs from plant to plant, and usually from department to department in most plants. Personal time is usually agreed upon by management and labor as a fixed percentage addition to the production standard. Unavoidable delays, such as tool breakage, wait for material, part stuck in machine, etc., are usually calculated by ratio-delay studies.

As stated before, it is the rating process which is by far the major bone of contention. It is by this process that the rate setter mentally or otherwise evaluates the performance being observed against a "normal" pace modified by the individual difficulties of the job being observed.

Basically, the time study man makes two distinct decisions in this process:

1. He must formulate in his mind the concept of what a normal performance should be on the job being studied.
2. He must determine a numerical comparison between the observed performance and the concept described in 1.

The AFL-CIO has stated (21):

> Rating is the step of the time study procedure where the most judgment or guesswork is involved. . . . The concept of "normal" must by its nature be carried around in the time study man's head. . . . The very nature of rating opens it to abuse. By manipulating this rating factor, it is easy for the time study man to end up with practically any result he chooses.

A commonly heard statement made by time study men is that their rating is within the limits of plus or minus 5% of the true rating. The Society for the Advancement of Management, long worried about this claim, conducted a study of existing practices in industry to establish a concept of a fair day's work, and to develop films as a medium for training in rating (26).

Films were subsequently made of 24 different, simple industrial operations conducted at various speeds of performance. The films were then rated by 1800 time study men from about 200 companies and these films are utilized by time study departments throughout the country to test rate setters.

The two major fallacies of using these films seem obvious. For one, the likelihood of associating a concept of

pace on these films of non-industrial jobs with an actual operation to be observed is very remote. Consider the differences in weight handled, eye-hand coordination and physical handling requirements, alone, between the filmed job and the actual job—yet these factors go into the rating process as allowances to be mentally added to the pace observed.

Secondly, it has been found that the use of the same 24 films throughout the country leads to a memorization of the expected rating values. This has been admitted to the author by quite a few time study men from around the country.

At the Marquette University Management Center, aside from the basic work measurement courses given, a time study rating session, attracting over 75 people, is held each year. It has never failed but that when these men are confronted with films they have never seen before, a spread of plus or minus 15% exists. In fact, when shown one film involving the lifting of a flask to a table in a foundry, the range runs close to plus or minus 20%. It has always surprised me as to how these men could rate a task without even asking so obvious a question, "How much does the flask weigh?" They never do. When the results are in, and their range of values is made public, we ask them, "What did you think the flask weighed?" Even among foundrymen their replies vary between 20 and 65 pounds, when the actual flask weight is 45 pounds. On another film shown in March, 1958, the weight ranged from 48 pounds to 5 pounds per carton lifted. The results of the rating session demonstrated the raters' inability to adequately compensate for weight handled.

Much has been written by Industrial Engineers on the subject of rating, from close-minded righteousness that is not to be questioned, to those who would eliminate rating altogether. Adam Abruzzi has expressed the most extreme view when he stated (1):

> . . . work measurement is actually reduced to a bargaining problem which, it will be shown, can profitably be considered within the theory of games. . . . In fact, the explicit admission that rating and specification-setting are a game rather than scientific processes would in itself be of advantage to management; it would prevent successful labor challenges simply on the basis that the process is not scientific.

Ralph Presgrave has stated (14, p. 194), ". . . time study still remains as much an art as a science." Arthur Sylvester (17, p. 5) and Dr. Gomberg (6, p. 191) have pretty much taken the same position.

A whole host of men have developed predetermined standard data systems. The major claims made for these systems is that they introduce the element of consistency and accuracy. As to accuracy, it must be considered that the system's accuracy is dependent on the system's rating process and choice of elements. If that is dubious, so might we consider the system. Yet, in seeking a new Utopia, a great many companies have seized upon these systems without checking this factor.

As to consistency, no system can possibly give all the data necessary to compute all performance standards. Values must be calculated and added to the system's values. How should these values be rated in order to be consistent with the standard data system?

Considering all of the above, is it any wonder that the AFL-CIO has stated (21):

> Time study has become a major issue in union-management relations. Unions have found that grievance handling problems are greatly increased in plants where time study exists. Not only are there more grievances, but a greater amount of time must be spent in investigating and processing time study grievances. . . . One local union recently reported that in the first five months of the year it had . . . 254 grievances . . . 221, or 87% were time study cases.

This article went on to quote statistics of the American Arbitration Association that, in 1954, time study and job evaluation were responsible for 19.1% of the cases handled and by 1956 this had risen to 23%

Do the prospects of never finding a solution to the rating problem seem likely? I very definitely think not. One of the major problems to overcome is the problem of most Industrial Engineers—overcoming resistance to change, but this time it's their own resistance to change. There exists today a system of rating which reduces much of these mental calculations to tables of values and films. This system is generally called objective rating and was first introduced by Dr. Marvin E. Mundel (12). A subsequent book describing this method was published by Dr. Gerald Nadler (13).

The basic feature of this method of rating is in separating pace or speed rating from job difficulty adjustments. Rating a job for pure pace (or speed) alone is much simpler than rating pace and adjusting for difficulty at the same time. Therefore, films of various "bench mark" paces, chosen for each plant if necessary, provide an anchor that will not shift with time.

Tables of values for the necessary adjustments are provided. These adjustments are for:

1. Amount of body used.
2. Bimanualness.
3. Foot-pedals.
4. Eye-hand coordination.
5. Handling requirements.
6. Weight handled.

The rating of a task can now be questioned and examined either through instantaneous review of the pace at time of study, a subsequent review of the tables of secondary adjustments, a review and rating of a film of the task, or all of these.

The problem of rating is still with us in most areas of the country. However, as was stated before, the pendulum has a way of returning. Management in many areas of this nation is on the defensive regarding the rating process utilized. Yet, the performance standards for machine paced operations are easily set and rating is not

a problem. The trend is more toward manpower's use as a machine tender rather than a machine operator; therefore, we can look to more easily set and less controversial performance standards in the future. It will then herald the era where the onus of productivity will be placed on labor, now to be paced by the machine.

SUMMARY AND CONCLUSION

It has been shown that wage incentives as we conceive them today, are a distinctly effective motivating force in bringing about increased productivity. The present systems of payment by result depend upon a realistic and workable payment plan as well as an objective method of determining standards of performance, as opposed to the rate cutting and "soldiering" of 50 years ago.

There also appears to be a correlation between the increase in real wages, the corresponding increase in productivity and the extent of wage incentive coverage in the U.S., Britain and Australia. This indication bears investigation that may very well provide further information as to the reasons for the degree of difference in productivity and real wages in these three countries as well as in other free enterprise nations.

One of the main reasons for management's desire to install and maintain wage incentives is the over-all reduction in unit costs which results when the more or less fixed overhead is now spread over increased units of product. Further gains to management are evident in reduced inventory costs and more flexibility with regard to scheduling smaller blocks of production time.

That the use of wage incentives has increased productivity by an average of 25% has not only been shown in a preceding chapter but is also borne out by this author's own experiences. When one discusses averages, however, one must be cognizant of the fact that each average represents a range of approximately 1 to 2 between the slowest and fastest workers. Therefore, incentive earnings between 130 and 140% are not as uncommon as the study of averages might indicate.

One of the main objections of organized labor has been with regard to the dissolution of traditional wage relationships. These differences develop as the increased productivity on lower job evaluated tasks gains for these employees wages which may approximate the wages of lower productivity employees on higher evaluated jobs, or even perhaps the non-incentive employees on a professional or supervisory status. The main objection is never quite expressed, but relates to the pinpointing of "slackers" and producers. Even in the intermediate range, a productivity evaluation can be made for each employee on the same or different jobs—differences which never became apparent through time wage systems.

Although many managements still insist on the sanctity of their performance standards, recent arbitration rulings indicate a trend towards the insistance that unions be allowed to see and review performance standards. This seems only logical when it is considered that the take home pay of its membership is directly affected by these standards. If there is nothing to hide and standards are set as objectively as possible, these rulings probably will not alter the equilibrium.

There exists today a system for reducing the factors that must be carried in the time study man's head. This system of objective rating has proven its ability to reduce the range of error from job to job, no matter how remotely that job resembles anything the rater has ever seen.

Although many studies have been conducted to indicate that money is not the number one primary reason why men work, I believe the results of these studies bear stratification. The results might be much more acceptable if they were classified as between incentive and non-incentive employees. I would venture to guess that money would be a much more dominant factor in the mind of the incentive worker, whose take home pay is a result of his own productivity.

The conflicts over wage incentives are not settled as of today, but it is a clear fact that the payment of wages by results conforms to our concept of free enterprise, as long as no definite advantage exists by either management or labor with regard to upsetting the equilibrium heretofore described. Wage incentives do provide a means of crediting employees for results as well as singling them out for recognition. Most important of all they provide a means whereby American industry can increase or maintain a high level of productivity for a given capital investment. Any student of economics can express the resultant advantages in terms of other nations in not so favorable a position.

The philosophy of wage incentives is sound and the union attitude is healthy as regards the protection of the employee from abuses by the system, intentional as well as unintentional abuses. It is the union's alertness that has caused management to devise better systems of incentives as well as better methods of measurement. We can look forward to more progress in the field of wage incentives if both management and labor continue their efforts to improve the techniques of increasing productivity, while being well aware of the other's interests.

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Training Practicing Industrial Engineers in Mathematical Techniques—A Case History

by **ROBERT MASKEL**

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LIKE most Industrial Engineers, I have been evaluating the pros and cons of whether Operations Research is Industrial Engineering or is in reality a separate profession. Although I still have an open mind on the subject, I have come to one definite conclusion, i.e., the use of mathematical techniques, especially statistics and probability theory, has much to offer the Industrial Engineering field as it stands today and for the future. This very important conviction becomes more apparent to me each year.

From this conviction it is apparent that Industrial Engineers should use these mathematical techniques. This is easier said than done, especially for those Industrial Engineers now on the job who have had no formal training in school. This problem faced us here at Spruce Falls and we have gone a long way towards solving it, by a combination of methods.

ACTUAL EXAMPLE

Four years ago we had 4 graduate engineers, only one of whom had had one basic course in business statistics during college. However, we did have two other assets which proved invaluable—1. an interest in the subject, 2. a practicing statistical quality control program administered by another division. Our biggest liability was our isolation. The nearest engineering educational institution is 540 miles away. (We probably have the distinction of operating the most northern Industrial Engineering Department on the American Continent.)

The first problem to surmount was to get some one person in the department to acquire a working knowledge of the subject. I did this myself, since I had the most interest and had had one basic course in business statistics at college. In looking back I now realize that the only good this course did for me was to whet my interest, since the coverage was very scanty. My first step was to get some books and work at home, with considerable help from the Quality Control people. After some study I decided, with more courage than knowledge, that I would teach a basic course in statistics to the other 3 members of the Industrial Engineering Department. So a 40-hour course was started that would be conducted outside

working hours. Other professional personnel were invited to attend and the class totalled 13. It was a complete success. Certainly it left me impressed with the old axiom that—the best way to learn a subject is to teach it. The results were good enough that we could immediately start to use what we had learned in our every day work. A year later the course was run again for 15 other personnel. Most of them had heard about the course from the previous year and requested that it be run again. This time I taught most of it but used the others in the Industrial Engineering Department for teaching part of it. We plan to offer it again next year and will have two Industrial Engineers, other than myself, conduct the complete course. This has two advantages—1. they must thoroughly learn the subject to teach it, 2. it gives them invaluable experience and confidence in speaking before a group.

OTHER PLANS

Our second step was to get more advanced work. Two of the Industrial Engineers were given an assignment to learn and then conduct a course on the Design of Experiments and the Analysis of Variance, for the rest of the department. This was done with good results. We are contemplating putting this on as a voluntary course for other interested people at some future date.

Another medium we have found useful is to assign someone an article to review from one of the magazines covering the field. I am happy to say that most of these articles have come from this *Journal*.

Another method that is becoming more useful now that we are conversant with the basic ideas is to purchase books and *encourage* the individuals to read and study them. This is working out very well and we are currently studying linear programming and non-parametric statistics with this method. I like to use the comparison that it costs from $5.00 to $10.00 to buy a book but from $200.00 to ? to send some one to a conference to learn a special technique.

The proof of the pie is in the eating and also with our mathematical techniques. We now use them almost daily and almost automatically. However, at first we had to go out of our way to use them and in many cases it took us longer than our older methods. We would be lost without them now, however, especially in regard to the quality of our studies and recommendations.

SUMMARY

I have attempted to show how we, who are relatively isolated, have successfully taught ourselves how to use elementary mathematical techniques in Industrial Engineering. I hope this can serve as an example to others who have been procrastinating. We are quite proud of our modest beginning and hope to continue on into more advanced techniques.

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Why Do Unions Oppose Management Determined Performance Standards?

by **W. R. HUDSON**

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IT SEEMS at times as though we are witnessing the beginning of the end of performance standards determined by means of the body of techniques, known loosely as work measurement. The union movement maintains a locally variable but generally constant harassing fire at these techniques, particularly at direct time study. Some of our managements are retreating, by various routes and to different distances. Industrial Engineers, even some good Industrial Engineers, are beginning to be doubtful. It is entirely possible that a certain amount of loss of perspective is responsible for these reactions. This discussion is offered as a perspective view.

This discussion will be organized around four points which are not necessarily exhaustive.

1. The use of management determined performance standards as a factor in wage determination conflicts with a basic logic of unionism.
2. The actual form of the union attacks on such standards is a rationalization.
3. A corresponding basic logic of management should be recognized by management people.
4. Because of differing environments, management people and union people can be expected to view such standards differently.

BASIC LOGIC

In assessing the logic of unionism relative to these standards it is well to begin by remembering that union opposition is not a recent development but dates from at least as early as the time of F. W. Taylor. The modern aspect is the increasingly specific approach used to attack standards; the union leaders are becoming quite skillful in searching out specific points in studies as the basis for upsetting the corresponding standard. There is nothing necessarily objectionable about a specific approach, indeed to the extent that faulty applications are revealed whereby a positive contribution is made. The questionable feature is the extension of specific cases of faulty applications to a generalized indictment of a whole body of technique. This generalization may be summarized as having two central themes.

1. The techniques are non scientific and inaccurate.
2. Performance and wages should be determined by "democratic process."

The basic logic of unionism would require opposition to management determined performance standards as a factor in determining pay and promotion regardless of the actual accuracy and scientific status of the techniques used. The reason is that the usual processes of determination and application of production standards tend to conflict with the most basic of all union needs, i.e., "union security." Many of us forget that for most of its history the major problem of America labor unions was to stay organized. Union leaders as a group are probably not so forgetful. Union security has to do with the strength to assure existence and status and is related to loyalty of the membership to the union per se and/or in the persons of its leaders. Over any appreciable period, loyalty is related to the extent to which the members see the union as the source of "good things." Amount of pay is an important one of these "good things." If the members' image of the union as the source of good things becomes confused, loyalty is endangered, hence "security." The almost invariable inclusion of wage demands in contract negotiations and the frequently found contract provision for prior union approval as a condition to selective pay increases initiated by management are both consistent with this logic.

Pay based on individual productivity is, within this logic, a form of selective systems of rewards whose benefits may not be clearly ascribed to the union's actions. There is thus a conflict with basic logic, hence such systems should be opposed as general policy. There may be over-riding local considerations which suspend local application of the general policy, but it is only suspended, not discarded.

RATIONALIZATION

The second point is that, in a real sense, attacks *on the techniques* used to determine production standards are a rationalization, i.e., the way in which the *real* sources of concern are expressed. An important difference between a "true cause" and a "rationalization" of that cause is that the former usually "makes sense" in accounting for all related behavior while the latter does not. The discussion just finished is an attempt to show

that there is a true cause for opposition which makes sense in its logical context. Turning now to the rationalizations, "inaccurate and nonscientific," it should be noted in passing that there is no universally accepted, exhaustive and explicit definition for either of these terms. Because of this, it is always possible to set up a plausible definition which cannot be met by a particular body of technique.

The "non scientific" charge is based on the use of performance rating which does, in fact, constitute an introduction of observer judgment into the interpretation of the data. In this view the ratings are not data, however, if one wishes to insist that they are, then it would have to be recognized that they are a different *kind* of data than the time values themselves. In either event the ratings are, from an operational viewpoint, a set of notations made so that the meaning of the time values may be interpreted for a specific purpose. A great many Industrial Engineers are dissatisfied with a situation in which the current state of knowledge does not permit use of a more objective basis for interpreting the time data. It should be recognized that criticism based on the need for any interpretation at all is likely to remain a permanent criticism. For example, if it became possible and practicable to measure levels of worker energy output under field conditions, it would still be necessary to interpret the meaning of a given level of energy in terms of "reasonable," or "normal" or "fair."

Relative to rationalization, the technical problems are not directly to the point. The central point is that the stipulated reasons for opposition to production standards are *not* used as a basis for opposition in other but equivalent situations. For example, a *stated* reason is inaccuracy, the objection is not restricted to *instances* of "inaccuracy" but is an objection in principle, i.e., an entire body of techniques is included. Regardless of the problems of defining "accuracy" it would seem that an objection in principle concerning "accuracy" should apply to all factors determining wages. This is obviously not the case since the procedures used in determining the cost of living index, or wage classifications, or base wage rates can hardly be characterized as "accurate" in the same sense demanded of work measurement. Yet these other factors are widely accepted without the question of accuracy being raised at all. Furthermore, although there are obviously very large elements of subjective judgment involved in deciding what is "reasonable," "normal" or "fair" relative to these other factors, this is also accepted without question as to technical respectability.

Additional contradictory behavior includes the fact of actual participation of locals in determining production standards and at least one instance in which the union bore primary responsibility for determining piece rates. The same techniques attacked elsewhere as being "inaccurate" were used in these situations.

Lastly, if "inaccurate" standards set by company analysts are unacceptable but performance standards (of some kind) determined by the workers themselves are acceptable then, presumably, the accuracy of such worker determined standards is superior.

BASIC MANAGEMENT LOGIC

Concerning the basic management logic relative to such performance standards, it is recognized that here also there may be over-riding local factors which produce a suspension of what would seem to be the logical long term position. So long as there is a recognized long term position, departures from this position will be viewed as temporary expedients of strategy. In the absence of a recognized long term position, the total price paid for relief of pressure could turn out to be very high.

The remainder of this discussion is intended to point out some of the considerations which should go into a decision as to the nature of basic management logic relative to performance standards. Some people apparently believe that there is a choice between having standards and not having standards. In any practical sense, this is not the case. There will always be a performance standard set by someone in some way. A performance standard of some kind is a functional necessity in virtually every phase of our everyday existence. The service station operator cannot confirm a requested delivery hour for a "wash and grease job" without using some kind of performance standard in his calculations. You cannot confirm (or reject) a proposal that you be at a certain place at a certain time without first going through a mental process involving performance standards of some kind. In the industrial situation if the performance standards are not otherwise determined the worker will certainly determine his own. By implication and direction this seems to be the nature of the alternative which those attacking work measurement have in mind. The question here is, does the alternative have promise of being superior in accuracy and scientific nature? This author has never seen a case made as to whether this is so, and will leave the reader to speculate on the answer.

Even though no case is made for superior accuracy and scientific nature: are worker determined standards better because they represent use of democratic processes? This subject could be given a lengthy discussion, but let it suffice here to ask a few questions.

Is a "democratic" (group) decision necessarily a "good" decision?

Does the fact that a decision is made by a group necessarily qualify the group to make decisions of that kind?

Is the "group," in the context in which we are speaking, equivalent to "society," so that a decision deemed by the group to be good for it will be also good for society?

The general question is whether the alternative (worker determined standards) promises to be superior technically and/or socially.

DIFFERING ENVIRONMENTS

This leads to a fourth point, the union people and the management people tend to operate in differing environments and this state will tend to influence the answers to the preceding question.

For example, views as to the social function of industry may be grouped into two general classes by major emphasis:

1. The prime obligation of industry is to produce goods (or services) in the kinds and quantities and at the prices desired by the society. This may be referred to as the "production viewpoint."
2. The prime obligation of industry is to provide a source of income for those associated with (employed within) the industry. This may be referred to as the "income viewpoint" or "purchasing power viewpoint."

Each viewpoint in its totality includes the other. The difference is in emphasis or view of the prime function of industry. The question of which alternative means of determining performance standards promises to be the more oriented toward productivity is an important one to a person holding the production viewpoint. Within wide limits, the same question is relatively unimportant to a person holding the income viewpoint.

Among other environmental differences between manager and union leader which tend to color viewpoints toward means of determining standards are the following:

Popular political ability is a much greater determinant in the selection of a union leader than of a manager.

Productive capacity is a minor factor in a union leader's evaluation of a member but is a major factor in management's evaluation of a worker.

The union leader's principal field of interest and action is in only one of the major factors of the total operating problem, labor. Management people are jointly responsible for the results of decisions in all factors of the operation.

The union leader is severely limited by his environment in opportunity to modify, reverse, or abandon a popular position or contractual provision. Management people are expected to make revisions and changes to keep in step with the current situation.

SUMMARY

1. Attacks on accuracy and scientific status of techniques for determining standards may arise from causes independent of those stated.
2. When such attacks are made, the nature of alternative techniques as to accuracy and scientific status becomes a pertinent question.
3. Union leaders and management people can be expected to have different bases for defining a "good" way of setting standards. Management people should weigh the total consequences of accepting the union's basis for definition.
4. Both parties might do well to concentrate on specific definitions of "accurate" and on the elimination of incompetent persons from the function of determining standards. In its intended sense "competence" also includes ethical competence.

Files in a Production Control System

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THE purpose of this article is to describe a way of looking at the data handling aspects of production control systems which has been found useful by the author. Unquestionably, the key parts of a production control system are the decision-making procedures. But these will not work correctly with poor data. Given the decision-procedures (or a desire to clean up the data system to prepare for improved decision procedures), a data system based, in concept, on the seven files described below is often more effective than one in which the files are added as the need appears to arise during the design. In practice, of course, the files may be geographically and functionally divided; but only for good reasons, if the proposed approach is taken. We start by reviewing the nature of files.

WHAT ARE FILES?

The full nature and implication of a file of data in a business will become apparent later in this article. In order to prevent misunderstanding let us try to define a file briefly here.

A file is a collection of records which is available to a data processing system in some well-defined manner and which is processed so that the records are as current as possible. A record, in turn, is defined as the data which is being retained about some aspect of an entity which is important to the operation of the business; entities such as employees, materials, machines, etc.

For example, a raw material inventory file contains a record for each type of raw material. The raw material is the entity. Usually the file is sequenced by a raw material code number so that records may be easily located

and reinserted. This sequenced collection of records is the file.

A group of purchase requisitions waiting to be processed is not a file. In the first place the purchase requisition may contain only part of the data desired about the entity. Also, the data is not available in a well-defined manner. Finally, this data is not kept current, but is in fact data being used to keep some other records (open order file records) current. On the other hand, a report of all open customer orders by type of assembly ordered say, which is issued monthly, but which is posted to and kept current during the month *is a file*, even though it is referred to as a report. A record in this case is one line or entry of the "report." A scheduling board is another form of file.

WHY HAVE FILES?

Files have become such an intimate part of a business' data processing system that one never hears their purpose questioned. Line management, in particular, tends to take files and the data they provide for granted and are often not aware that files exist (yet sometimes they wonder why their clerical staffs are so large). It is a good policy to question any business function from time to time, especially those for which the necessity is "obvious." Why then do businesses become burdened with so many files and records?

The principal reason for files in business is to act as the *memory* of a business: Even the smallest businesses have become so complex that no one person or group of people can recall accurately (if at all) all of the events which have occurred during a past period of even a day which affect the financial position and therefore the profits. For example, it is well known that job labor reports filled out as the jobs are done are more accurate than if the worker tries to complete his job card at the end of the day. Management especially has become so complex that a manager cannot possibly remember all of the facts pertinent to his decisions. Imagine trying to remember the load (hours of work) for even 10 machine centers, with jobs being completed and new ones arriving constantly; and this is only part of a shop order control manager's job. Files are necessary if the data required to run a modern business are to be available.

But since the memory of the business must now be in a mechanized form, recorded by some physical process, *management has to be very specific about how the files are kept and how they are used.*

After all, files are kept basically to allow management to get the data it needs to make decisions, not for the sake of data processing groups! So it is up to management to define the basic facts about the files; namely:

1. What files should be kept?
2. Exactly what data should be maintained in the files?
3. How up-to-date should the files be, that is, how often should they be processed?
4. What data should be extracted from the files for reports and how should the report data be prepared (summaries, statistical analyses, etc.)?

Actually, management usually does not completely specify the file structure in this way. All they should have to do is define the reports and data required and the frequency with which they will be required, and the way they will be used in decision-making (step 4). Then an experienced data systems designer can decide the most economical way of establishing the files (steps 1, 2 and 3) to obtain these outputs.

Having decided that files are the memory of the business one might ask, why have a memory? There are several reasons. Memory permits *comparisons*, it allows the *association* of data about different aspects of the business, financial and physical; and finally it permits better *control*.

There are three ways in which files are used to make *comparisons:*

1. Files permit one to compare the order for an activity or a financial transaction, with the actual result. This is vital to the control of the activity. If it were not possible to remember what the orders were in some easily accessible way, it would not be possible to determine if the proper actions had been accomplished. For example, one would not want to go out into the shop to find a particular shop order document to see what its progress is. Instead, one sets up a file giving the key data about the order and then posts progress report data to it, so that to determine progress it is only necessary to consult the file (if the data processing system is accurate and timely).
2. Files permit the comparison of present status with budgeted position and with policy. (This is the same type of function as in 1., except at a higher level of management.) If manufacturing management has made it a policy that not more than 40% of the fabrication in the machine shop should be sub-contracted it is necessary to file the data about each job including whether it is done in the plant or not. This data can then be summarized at the proper time to obtain the percentage of jobs actually sub-contracted.
3. Files allow the comparison of past results with present results. It would be impossible to make this comparison without filing, or storing the information about past events somewhere. The comparison with past events and previous statistics is important for two reasons. First, in complex situations, often the guide to future action is based on past history, i.e., on experience or quantitative "know-how." For example, it is difficult to set sales quota in a small-volume, engineered-product business from market surveys. There is not a large enough sample to make a survey significant. Instead, management must use previous years' sales statistics to judge performance. Second, comparison of the past with the present allows the calculation of trends, which in turn make possible some estimates of what will happen in the future.

Files are used extensively to permit the *association* of data obtained from various sources. For example, we wish to compare an employee's time card data with his hours reported on job cards. Or, it is usually necessary to correlate the receipt of material from a vendor (data obtained from receiving at one time) with the cost of the material (data received from accounts payable at another time); so that when the material is used in fabri-

cating a part, the cost of the part can be computed. In other words, the file retains data until all phases of a transaction are completed; it compensates for time delays.

The fact that management and other reports are only required periodically and yet data for some reports are being generated continuously means that the data must be held (filed) somewhere. Reports of progress on the jobs in a shop come in whenever an operation is complete, but the procedure might be to check the progress and prepare behind-schedule reports only weekly (for example) so that during the week the progress report data is filed.

(For those with an engineering background, the relationship between files in a business and storage devices or integrators in a servo-mechanism will be recognized. Servo integral control systems and other forms of control, even those which include a computer in the loop, are much simpler than any business system. Nevertheless, there is hope that some day analytic techniques will be available for use in business systems just as they now are in servo systems. It must be recognized that at the present time, the design of a production control system is largely an art.)

To summarize the nature of business file systems, it is useful to think of files as an analog of the actual business activity. The data about the business: the capital used, the decisions made, the activity that actually occurs (both services and material processing), and the financial results of the activity are all recorded in files. Thus at any moment the files reflect the actual status of the business. With this analog it is then possible to manipulate data and extract it so that management can get a picture of the status of the business which in ancient times a business manager obtained by "walking through the shop."

A production control system consists of an analog of the production processes, which means it contains the production control files, and the processes for: 1. maintaining the files current, 2. processing the file data to obtain desired reports and 3. decision-making people who actually exercise the control by 4. issuing orders.

WHAT FILES ARE REQUIRED?

Having decided that some files are required, the questions are: For what data will files be kept? In what sequence, and what data shall be recorded in these files? Any production control system now in use will have many files, for example; raw material files, parts inventory files, sales order files, cost accounting files, employee labor files, machine tool files, etc. On the other hand, there may be data gathered and reported upon that never actually appears in what might be thought of as file form. For example, a report of production requirements might be issued monthly. This may be regenerated each month from the basic customer sales orders. Should a file of parts requirements be maintained? To answer these questions, let us ask: What are the basic entities in a production system about which we must have data?

The basic entities in Production Control are shown in Table 1.

We do not include vendors in these basic files, since it is presumed that purchasing (outside of production control) makes all choices of and contact with vendors. Purchasing files of course interrelate with production control files. Also not included are such entities as stockholders and creditors, and others which come in only when discussing higher levels of management or other functions, such as accounts payable but not production control. Engineering "entities" such as (possibly) a catalog of design techniques known, are not the concern of production control. The engineering and manufacturing engineering data as to how to build a certain item is part of the data relating to that item and would fall in category 4 of Table 1.

Thus it is contended here that, conceptually at least, only seven files are required in the production control process. In what follows we discuss briefly how the normal production control processes fit into such a file system. The next section covers how the financial functions are related to these files.

To show that these seven files will fulfill all production control requirements we have to show that they can contain sufficient data 1. to make all required management decisions (at least those which occur with any frequency, say yearly or oftener); 2. to meet all legal requirements, in particular in respect to preparing proper payrolls, paying vendors, shipping proper items and providing required government reports. A little study will show that the physical control processes can be accomplished with these files, if each file contains sufficiently complete and current data.

FINANCIAL ASPECTS OF FILE DATA

The financial data associated with a physical process, a material item or an act of service measures the monetary value of same. The value of the item is actually determined only when the price is agreed to by the customer. This may be either before or after the item (or group of items) is made. In order to permit management to control the operation it is desirable to know the "cost" of the item; which is to say, the monetary value of the services (including labor) and materials that went into the item. This cost is management's estimate of the "value." The cost may be determined in two ways: by accumulating the costs as they are incurred or by allocating the total costs after the item is completed, or by a combination of the two. However, it is not always possible to accumulate costs as they are incurred. This is because of material waste, and because of the generalized nature of some services within the company, such as rent.

TABLE 1

Basic Files for Production Control

File	Sequence	Basic Data
1. Customers	by customer name or code number	orders placed, shipping address data for demand statistics, dollars on order, billing data, credit rating
2. Equipment owned or rented (this includes plant, machines, tools, trucks, etc.)	by type and serial number	description, cost, depreciation, capabilities, location, future load or useage data, maintenance records
3. Operations (a catalog of processes which can be performed, including material processes, inspection, moving and handling, and services, such as, making estimates)	operation number	description, standards of performance and cost, actual performance and cost, how performed, where performed, equipment and labor skills required
4. Materials (raw material, semifinished and finished parts and assemblies, general supplies, fuel)	material number	description, directions for fabricating, standard and actual cost (including incentives), quantity on hand and on order, useage data, location
5. Orders (to perform specific operations on specific material)	order number	operations, sequence, due dates, material requirements, cost accumulations, status, location
6. Employees	employee number	identification, skills, availability, rate of pay, present assignment
7. Accounts (temporary files)	account number	identification, amount

Since all costs incurred by a company must be covered by income from products made (insofar as a manufacturing business is concerned) all costs must be associated with the products made. Even when a part is sitting on a shelf it is accumulating cost. Presumably, on the average, the product price exceeds the cost. It is assumed here that the purpose of a cost account is to allocate costs to items in such a way as to give management the data it requires to *control* costs and make estimates and so to maximize profits. Cost accounting has two aspects, 1. data processing; gathering and allocating costs and 2. establishing the methods of allocation.

The methods of allocating costs are in the area of finance, but they also affect the data available to production management for controlling the production processes. Therefore, it is legitimate for production management to influence the methods of cost accounting, and to include the cost accounting data processing within its area, if that is the most economical way to get the required timely cost data. We, therefore, consider production costs further.

MATERIAL COSTS

If there were no scrap or waste, the determination of material costs would be straight-forward. In the presence of waste factors, it is necessary to apportion the cost of the wasted material to the items produced.

SERVICE COSTS

If services were paid for only when they directly affected a produced item, then the costing would be straight-forward. Actually many services are paid for on a time basis, and the number of items produced per unit of time varies, that is, there is wasted time. Furthermore, where several items are affected by the same service, it is sometimes difficult to decide how much of the service is apportionable to each. In both cases then there is a problem of allocating service charges. The generally used accounting procedure is to accumulate all of the charges which cannot be related directly to a productive process in separate accounts, called "overhead" accounts. After a certain period, the accumulation is then allocated to the units produced during that period. The method of allocation is a management decision, and it is not our purpose here to question any particular method of allocating overhead. Allocation in proportion to direct labor hours, and/or machine hours is common. A choice has to be made also of the various overhead accounts that will be set up: for example, will the cost of rejected parts be accumulated as part of general factory overhead, or accumulated separately for each lot? This again is a management choice.

The net effect of overhead allocations is that certain costs cannot be associated with the record of a produced unit until sometime later, that is until the end of the period when the accumulation is to be allocated.

One other source of delay in assigning costs is that the cost of services rendered by vendors is not known exactly until they submit an invoice, which may be some time after the materials are received.

If it were not for these delays, it would be possible to accumulate the cost of each item produced as it is produced. Even with these delays it is possible to accumulate estimated costs for each item produced. Where the cost is required soon after each step of production, then the delayed costs can be estimated, and corrected later in variance accounts which one hopes are small.

As a result of the necessity for overhead or accumulation accounts, the seventh set of files is actually required, a file of accounts. Charges are added to this account, and later removed to be allocated to records relating to particular items.

Probably the most important point is that the cost of an item is just another characteristic of the item, similar to its part number, its quantity, its size, etc. The cost can be retained in the same file record as all of the other items of information about the part or assembly. There are only two reasons for not keeping cost data in the same file as other data: 1. it is shown that *data processing* costs are lower, if a separate file is maintained, or 2. a separate file is required for reasons of internal control, that is to reduce the chances of error and fraud. In general, separate files are justified where manual or tabulating data processing equipment is used for both reasons, but usually not where electronic data processing equipment is used.

In concluding this part of the discussion on the financial aspects of files, we can summarize by stating that, in principle, the financial data is a part of the seven basic files previously described.

SUMMARY OF FINANCIAL FILE CONTENT

Included in the customer files are these financial data: dollar value of units on order, accounts receivable data and credit data. As far as a production control system is concerned, however, the customer file does not need to carry any financial data.

Included in the equipment-owned file would be the original and depreciated value of equipment, burden rates for use of the equipment, etc. The one quantity important to production control is burden rates, the cost of using this equipment either per unit of time or per unit produced. (Management levels higher than routine production control determine the methods of setting this

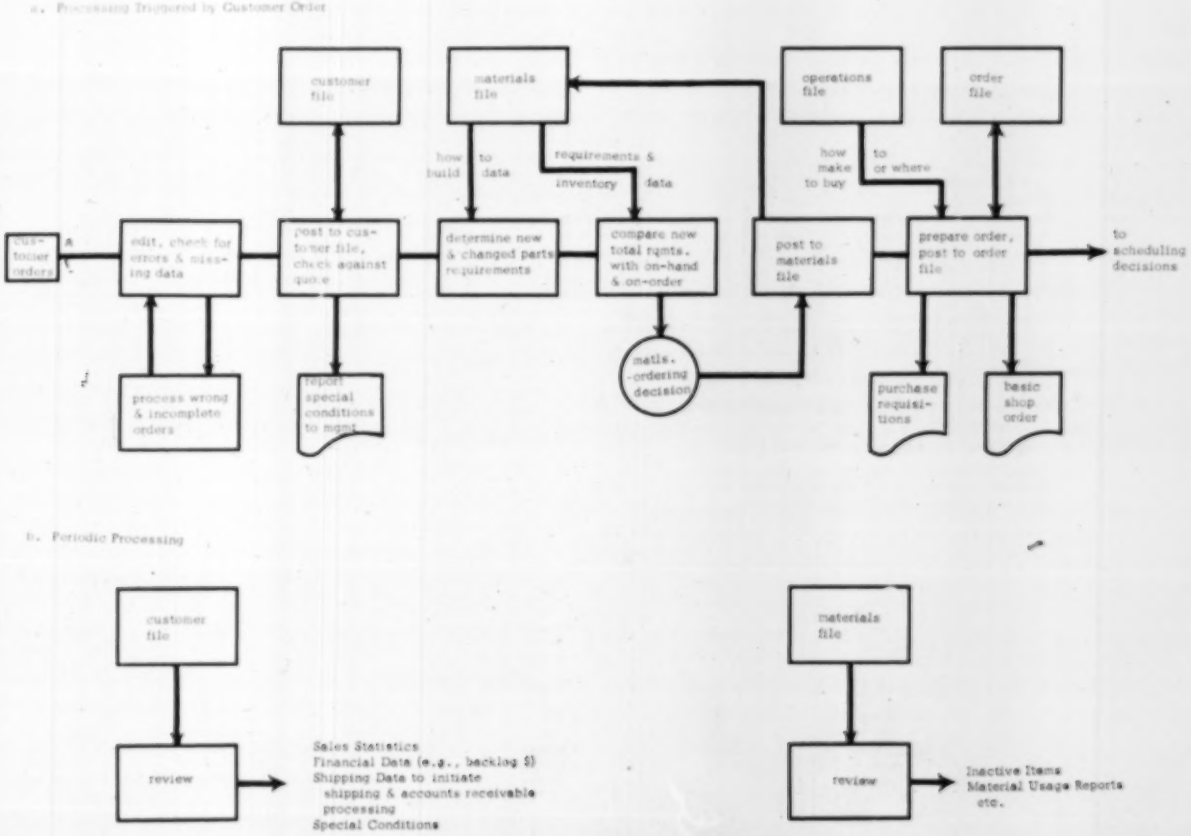

Fig. 1. Customer Order Processing

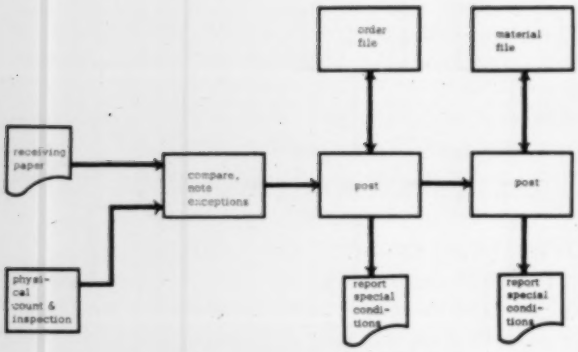

FIG. 2. Processing a Receiving Report

rate; financial and production management would set specific rates according to these methods.)

In the operations file, the basic financial data required are the standard and actual costs of performing the operation. The standard is a figure against which to compare costs. Industrial Engineering would be responsible for determining these standards, generally.

In the materials file, the present cost of the material would be carried. This cost includes the original acquisition cost and all subsequent costs such as direct labor, direct material, machine use (burden rate) costs and all "overhead" costs properly allocable to the item. It should include, therefore, storage and inventory carrying costs. If there is an assembly in the stockroom about to be shipped, then the cost associated with this assembly will reflect the total cost of the item (except perhaps for some shipping costs). The cost of a purchased component part will reflect its purchase cost, plus purchasing, inspection, handling and storage costs to date. In practice purchasing, inspection and storage costs may be allocated at a later point. (It should be noted that the advent of electronic computers makes the allocation of such charges to individual items on a frequent (daily or weekly) basis feasible.)

Finally as stated above, there may be a set of files which temporarily hold accumulated costs (e.g., cost of operating a cleaning bath) before they are allocated (in this case, to all of the parts cleaned in a certain period according to size).

THE RELATIONSHIP BETWEEN FILES AND TRANSACTIONS, REPORTS AND DATA PROCESSING

Having discussed the nature of files and of a production control system, next we look into how data gets into and out of the files, to accomplish the information processing implied by a production control system.

In Figure 1a, we have portrayed the activities that take place as a result of the receipt of a new customer order. We are following a transaction flow. We note that as the information obtained from the customer order (and other sources during the processing) is processed, several files are affected. Noted that during this sequence

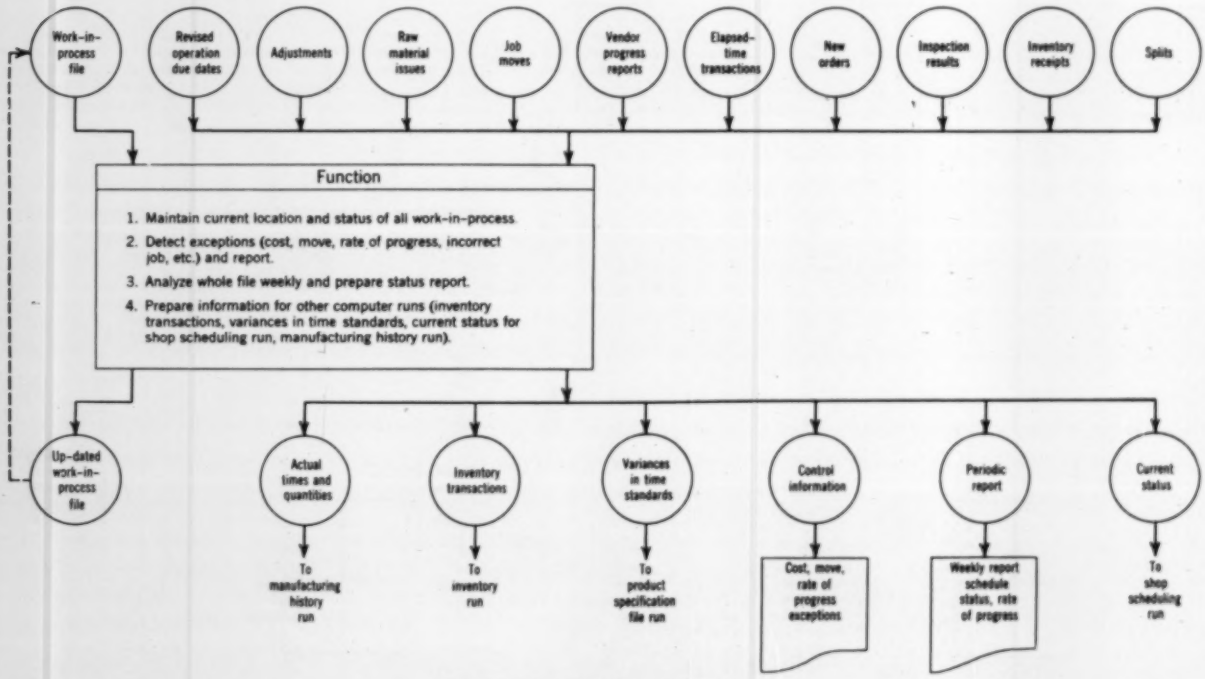
Work-in-process file
Revised operation due dates
Adjustments
Raw material issues
Job moves
Vendor progress reports
Elapsed-time transactions
New orders
Inspection results
Inventory receipts
Splits
Function
1. Maintain current location and status of all work-in-process.
2. Detect exceptions (cost, move, rate of progress, incorrect job, etc.) and report.
3. Analyze whole file weekly and prepare status report.
4. Prepare information for other computer runs (inventory transactions, variances in time standards, current status for shop scheduling run, manufacturing history run).
Up-dated work-in-process file
Actual times and quantities
To manufacturing history run
Inventory transactions
To inventory run
Variances in time standards
To product specification file run
Control information
Cost, move, rate of progress exceptions
Periodic report
Weekly report schedule status, rate of progress
Current status
To shop scheduling run

FIG. 3. Work-in-process File Run

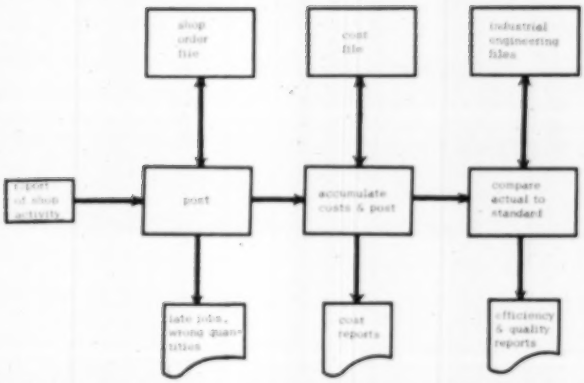

FIG. 4. Processing Shop Reports—Typical of Present Methods

there are created, in effect, new transactions as a result of decisions made. For each transaction, we go through the steps of interpretation, making a decision, posting to a file and issuing an order.

If we follow a feedback transaction, such as a receiving report, as shown in Figure 2, we go through the steps of recording, communicating, posting to a file, looking for exceptions and reporting. A study of production control requirements will permit a listing of all imputs and outputs and the files they affect. One can then isolate each file and determine all of the activity that relates to it. Figure 3 shows the activity which might relate to the shop order file. One of the principal differences between various production control systems is the particular files which have been established. Once the files are chosen, the processes which relate to them follow rather definite patterns, if a complete production control system is to result.

In Figure 4 the fabrication control or shop-order control function is shown being processed in three files: one for physical control, one for financial control and one related to quality and time standards. In Figure 5 all data relating to a shop order is processed through one file. *The design of a production control data system should start by assuming the seven consolidated files described earlier.* Fracturing or partitioning of the files may be required during the design of the system, in order to get a practical data processing procedure. However, fracturing a file without sufficient justification results in increased data processing costs and loss of control because of the following reasons:

1. With fractured files additional data processing steps to communicate data between files are required, and each entry to a file, extraction from a file and communication between files costs money. They also introduce time delays and errors.
2. Therefore, data for decision-making and control is delayed.
3. More data must be filed because descriptive data, at least, must be duplicated. (The part number must be in both the cost accounting and physical inventory file, if they are separate.)
4. Additional accuracy checks are required to insure that all files are the same.
5. For the more complex decisions, several files must be entered to obtain all of the pertinent data. For example, to make a decision as to whether and how many more of a certain part to order, we must have data as to (a) present inventory, (b) on order status, (c) requirements, (d) unit cost and (e) lead time. If these are filed in an inventory file, a purchasing file, a customer requirements file, a financial inventory file, and a manufacturing data file, then the process of getting all the data together for a decision is long and expensive.

It is important, therefore, to *start* the design with *consolidated* files, and to retain them unless the economies of the data system clearly indicate otherwise.

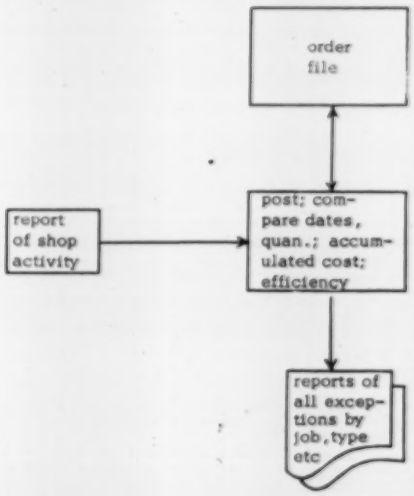
order file
report of shop activity
post; compare dates, quan.; accumulated cost; efficiency
reports of all exceptions by job, type etc

FIG. 5. Processing Shop Reports—Consolidated File

SUMMARY

Files are basic to complex information systems, of which production control is a prime example. By retaining and keeping up-to-date the proper physical and financial data in files, management has the data available to control operations and to serve as a basis for effective decisions.

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A Mathematical Method of Equipment Location[1]

by **R. J. WIMMERT**

Associate Professor, Department of Industrial Engineering, University of Florida

THE need for a quantitative method of locating equipment in the intermittent manufacturing plant has been recognized by Industrial Engineers for a long time. Until relatively recently, the only techniques available to the engineer have been various types of schematic models: process charts, process diagrams, two-dimensional templates, and three dimensional models. The very nature of schematic models requires the Industrial Engineer to develop and to evaluate alternate layout proposals by relying primarily upon his judgment and experience. Within the last few years more objective methodologies have been proposed by various people, but in the aggregate even these techniques rely to a great extent upon subjective evaluation. It is highly questionable whether judgment ever can be completely eliminated from Industrial Engineering. It is the opinion of the author that the following location technique will reduce the judgment factor to a minimum consistent with the assumptions made with the selected criterion.

To explain the proposed methodology, it will be necessary to discuss the properties of a special matrix that must be used. This will be done first, followed by an illustrative example and finally the mathematical proof of the matrix properties will be discussed.

Figure 1 depicts the special type matrix used in determining the optimal equipment location. The row headings are given in the general case a $A_1, A_2, \ldots, A_n$. Numerically these have monotonic nonincreasing values. Similarly, the column headings are given in the general case as $B_1, B_2, \ldots, B_n$. Numerically these have associated with them monotonic nondecreasing values. The matrix cell values are the product of the corresponding row and column headings; i.e., $X_{ij} = A_i \cdot B_j$. In a square $n \times n$ matrix such as Figure 1, there is a total of $n!$ combinations of X_{ij} terms in which exactly one X_{ij} term is used from each row and each column. Every term in the matrix will be used in $(n-1)!$ of the total $n!$ combinations. If all of the $n!$ combinations of the X_{ij} terms (one from each column and each row) were listed or ranked in non-increasing numerical value, the following would be true.

X_{1n}—would appear in $(n-1)!$ combinations of the ranked list before any other X_{ij} term.

X_{2n} & $X_{1,n-1}$—would appear in $(n-1)!$ combinations of the ranked list before any other X_{ij} term except X_{1n}.

X_{3n} & $X_{2,n-1}$ & $X_{1,n-2}$—would appear in $(n-1)!$ combinations of the ranked list before any other X_{ij} term except those noted above.

In general, the X_{ij} terms falling on the diagonals further from the main matrix diagonal will appear in the ranked list $(n-1)!$ times before the terms falling closer to the main diagonal. This order of occurrence is shown in Figure 2.

In order to show how this matrix property can be utilized consider the following illustrative example.

ILLUSTRATIVE EXAMPLE

A job-lot manufacturing company contemplates beginning a new operation within an existing building. It desires to place its four manufacturing machines in the four available areas in such a manner as to minimize the

	B_1	B_2	B_j	B_k	B_{n-1}	B_n
A_1	$X_{1,1}$	$X_{1,2}$	$X_{1,j}$	$X_{1,k}$	$X_{1,n-1}$	$X_{1,n}$
A_2	$X_{2,1}$	$X_{2,2}$	$X_{2,j}$	$X_{2,k}$	$X_{2,n-1}$	$X_{2,n}$
A_m	$X_{m,1}$	$X_{m,2}$	$X_{m,j}$	$X_{m,k}$	$X_{m,n-1}$	$X_{m,n}$
A_i	$X_{i,1}$	$X_{i,2}$	$X_{i,j}$	$X_{i,k}$	$X_{i,n-1}$	$X_{i,n}$
A_n	$X_{n,1}$	$X_{n,2}$	$X_{n,j}$	$X_{n,k}$	$X_{n,n-1}$	$X_{n,n}$

Where: A_i $i=1, 2, \ldots, n$ is monotonic nonincreasing.

B_j $j=1, 2, \ldots, n$ is monotonic nondecreasing.

$X_{ij} = A_i B_j$

FIG. 1. Special Matrix

[1] Based upon portions of a Ph.D. thesis written by the author while in the Department of Industrial Engineering, Purdue University, 1957. The author would like to express his indebtedness to Professors Amrine, Hicks, and Young of the Department of Industrial Engineering, Purdue University for their aid in developing this work.

	1	2	3	4	5	6	7	8	9
1				6	5	4	3	2	1
2					6	5	4	3	2
3						6	5	4	3
4							6	5	4
5								6	5
6									6
7									
8									
9									

Main Minimizing Diagonal

FIG. 2. The Order of Occurrence of Matrix Terms

total inter-department material move distance.[2] Although the company anticipates producing a myriad of different products, its product line can be classified into five major processing classes. The products falling within each class have substantially the same operation sequence, the differences between products being the size, color, etc. The monthly sales estimates and the operation sequence for the five product classes are shown in Figure 3.

The number of products moving between the various machines during a month must first be determined. To solve this problem, square matrices similar to the travel charts proposed by Cameron can be used.[3] The origin of the product flow will be shown as row headings. The main diagonal of these matrices must obviously contain only zero's since we are interested only in inter-department moves. In Figure 4 the monthly product flow for each class is shown.

In order to determine the number of material handling equipment moves necessitated by the product flow, it is necessary to divide the numbers appearing in Figure 4 by the number of units making up an average move quantity. These figures would naturally depend on the size, shape, skid arrangement, etc., found in the actual situation. By the process of matrix addition the total number of material handling equipment moves between the various machines can be ascertained. Since the criterion of minimizing move time is to be used, the direction of material flow is unimportant. The directional orientation appearing in the matrix is eliminated by adding the numbers appearing in the portion below the diagonal to the corresponding cells above the diagonal. In Figure 5, the result of the above mentioned operations is shown. This array indicates the total number of equipment load moves between the various machines.

The next problem that must be resolved is the determination of the distances between the work areas available for the four machines: turret lathe, drill press, milling machine, and inspection. This could be done by physically measuring the distance in the shop or by use of the available layout drawings. For this illustrative example, the distance shown in Figure 6 will arbitrarily be used. They have no significance other than convenience.

The entire illustrative problem is graphically summarized in Figure 7. The layout engineer must arrange the four pieces of equipment in such a manner as to minimize the summation of the product, material handling equipment loads times distances, i.e.,

Minimize $MD = \sum(L)(D)$

Where MD = total equipment move distance

L = material handling equipment loads being generated at the machines

D = distances between available area locations

Many of the classical operation research techniques could be considered as possible methods of solving the equipment-location problem. In their present state of development, these techniques cannot cope with a combinatorial problem of this nature. The properties of the matrix shown in Figure 1 will allow the systematic determination of an optimal or a near optimal machine-location arrangement.

In Figure 8, the loads between machines are arranged in a monotonic nonincreasing fashion from top to bottom, the distances between locations are arranged in a monotonic nondecreasing fashion from left to right. This matrix

PRODUCT CLASS	MONTHLY REQUIREMENT	OPERATION SEQUENCE
1	30 Units	T. L. - M. M. - Insp.
2	65 Units	T. L. - D. P. - M. M. - Insp.
3	75 Units	M. M. - D. P. - T. L. - D. P. - Insp.
4	120 Units	T. L. - D. P. - M. M. - T. L. - Insp.
5	45 Units	M. M. - T. L. - M. M. - D. P. - T. L. - Insp.

T. L. Turret Lathe
M. M. Milling Machine
D. P. Drill Press
Insp. Inspection Department

FIG. 3. Production Activity and Operation Sequence

[2] The criterion selected for this illustrative example is the total number of feet of material movement. It should be noted by the reader that this is only one of the many criteria suggested by the authorities in plant layout. The minimizing matrix can be used for many of the other criteria without modification.

[3] Cameron, D. C., "Travel Charts—A Tool for Analyzing Material Movement Problems." *Modern Materials Handling*, January 1952, Vol. 7, pp. 37–40.

From \ To	TL	DP	MM	Insp
TL	0		30	
DP		0		
MM			0	30
Insp				0

Product Class (1)

From \ To	TL	DP	MM	Insp
TL	0	65		
DP		0	65	
MM			0	65
Insp				0

Product Class (2)

From \ To	TL	DP	MM	Insp
TL	0	75		
DP	75	0		75
MM		75	0	
Insp				0

Product Class (3)

From \ To	TL	DP	MM	Insp
TL	0	120		120
DP		0	120	
MM	120		0	
Insp				0

Product Class (4)

From \ To	TL	DP	MM	Insp
TL	0		45	45
DP	45	0		
MM	45	45	0	
Insp				0

Product Class (5)

FIG. 4. Monthly Product Flow between Machines as Determined from Sales Forecast and Route Sheets

is clearly the same type as the one shown in Figure 1.[4] In this specific example there are 720, (6!), load-distance combinations possible, of which only 24, (4!), combinations would meet the restriction of one and only one machine associated with each location. The 720 combinations could be ranked from the highest numerical value to the lowest numerical value (the main diagonal, $i=j$). Each one of the cells of the matrix (load X distance) would be used exactly 120 times $[(n-1)!=(6-1)!]$. The matrix cell to be used 120 times first in the ranked list could be the one appearing in the northeast corner of the matrix; 53,960. This cell pairs the loads between the turret lathe and the drill press with the distance between location number one and location number four. Of the remaining 600, $[n!-(n-1)!]$, combinations, there are clearly pairings of this load with other distances which will give a smaller numerical value to the term $\sum_i \sum_j X_{ij}$.

[4] It is interesting to note that an optimal solution of the linear programming distribution problem of pairing loads with paths will always fall along the main diagonal of this specialized matrix. This property of the matrix could become valuable in certain linear programming problems other than equipment-location.

It is evident from Figure 8 that of the 24 feasible combinations, all may be eliminated in which the loads between the turret lathe and the drill press use the path between locations one and four. From the 24 feasible combinations, the following set of combinations should be discarded.

(*T.L.–D.P.*)—(*1–4*)

1. *T.L.*—1 *D.P.*—4 *M.M.*—2 *Insp.*—3
2. *T.L.*—1 *D.P.*—4 *M.M.*—3 *Insp.*—2
3. *T.L.*—4 *D.P.*—1 *M.M.*—2 *Insp.*—3
4. *T.L.*—4 *D.P.*—1 *M.M.*—3 *Insp.*—2

Eq. 1.

It should be noted that the equipment-location combinations are discarded as a group and not as a single combination. It is this property that makes this technique applicable to larger problems.

From Figure 2, it is known that the next two cells appearing $(n-1)!$ times in the ranked list, could be (*T.L.–D.P.*)—(2–4) and (*D.P.–M.M.*)—(1–4), thus eliminating the machine-locations combinations:

(*T.L.–D.P.*)—(2–4)

1. *T.L.*—2 *D.P.*—4 *M.M.*—1 *Insp.*—3
2. *T.L.*—2 *D.P.*—4 *M.M.*—3 *Insp.*—1
3. *T.L.*—4 *D.P.*—2 *M.M.*—1 *Insp.*—3
4. *T.L.*—4 *D.P.*—2 *M.M.*—3 *Insp.*—1

Eq. 2.

(*D.P.–M.M.*)—(1–4)

1. *T.L.*—2 *D.P.*—1 *M.M.*—4 *Insp.*—3
2. *T.L.*—3 *D.P.*—1 *M.M.*—4 *Insp.*—2
3. *T.L.*—2 *D.P.*—4 *M.M.*—1 *Insp.*—3
4. *T.L.*—3 *D.P.*—4 *M.M.*—1 *Insp.*—2

Eq. 3.

Using the same procedure on the next diagonal, the following feasible combinations are eliminated.

(*T.L.–D.P.*)—(3–4)

1. *T.L.*—3 *D.P.*—4 *M.M.*—1 *Insp.*—2
2. *T.L.*—3 *D.P.*—4 *M.M.*—2 *Insp.*—1

	TL	DP	MM	INSP
TL	0	380	240	165
DP		0	305	75
MM			0	95
INSP				0

FIG. 5. Total Loads between Machines—Nondirectional

3. *T.L.*—4 *D.P.*—3 *M.M.*—1 *Insp.*—2 Eq. 4.
4. *T.L.*—4 *D.P.*—3 *M.M.*—2 *Insp.*—1

(*D.P.*–*M.M.*)—(2–4)

1. *T.L.*—1 *D.P.*—2 *M.M.*—4 *Insp.*—3
2. *T.L.*—3 *D.P.*—2 *M.M.*—4 *Insp.*—1
3. *T.L.*—1 *D.P.*—4 *M.M.*—2 *Insp.*—3 Eq. 5.
4. *T.L.*—3 *D.P.*—4 *M.M.*—2 *Insp.*—1

(*T.L.*–*M.M.*)—(1–4)

1. *T.L.*—1 *D.P.*—2 *M.M.*—4 *Insp.*—3
2. *T.L.*—1 *D.P.*—3 *M.M.*—4 *Insp.*—2 Eq. 6.
3. *T.L.*—4 *D.P.*—2 *M.M.*—1 *Insp.*—3
4. *T.L.*—4 *D.P.*—3 *M.M.*—1 *Insp.*—2

Similarly the fourth diagonal shows the following combinations as being undesirable.

(*T.L.*–*D.P.*)—(2–3)

1. *T.L.*—2 *D.P.*—3 *M.M.*—1 *Insp.*—4
2. *T.L.*—2 *D.P.*—3 *M.M.*—4 *Insp.*—1 Eq. 7.
3. *T.L.*—3 *D.P.*—2 *M.M.*—1 *Insp.*—4
4. *T.L.*—3 *D.P.*—2 *M.M.*—4 *Insp.*—1

(*D.P.*–*M.M.*)—(3–4)

1. *T.L.*—1 *D.P.*—3 *M.M.*—4 *Insp.*—2
2. *T.L.*—2 *D.P.*—3 *M.M.*—4 *Insp.*—1 Eq. 8.
3. *T.L.*—1 *D.P.*—4 *M.M.*—3 *Insp.*—2
4. *T.L.*—2 *D.P.*—4 *M.M.*—3 *Insp.*—1

(*T.L.*–*M.M.*)—(2–4)

1. *T.L.*—2 *D.P.*—1 *M.M.*—4 *Insp.*—3
2. *T.L.*—2 *D.P.*—3 *M.M.*—4 *Insp.*—1 Eq. 9.
3. *T.L.*—4 *D.P.*—1 *M.M.*—2 *Insp.*—3
4. *T.L.*—4 *D.P.*—3 *M.M.*—2 *Insp.*—1

(*T.L.*–*Insp.*)—(1–4)

1. *T.L.*—1 *D.P.*—2 *M.M.*—3 *Insp.*—4
2. *T.L.*—1 *D.P.*—3 *M.M.*—2 *Insp.*—4 Eq. 10.
3. *T.L.*—4 *D.P.*—2 *M.M.*—3 *Insp.*—1
4. *T.L.*—4 *D.P.*—3 *M.M.*—2 *Insp.*—1

Through the process of eliminating the above mentioned combinations from a list of the 24 feasible machine-location combinations, only the optimal solution remains,[5] i.e.,

T.L.—3 *D.P.*—1 *M.M.*—2 *Insp.*—4 Eq. 11.

[5] The reader may check this by calculating the total distances for each of the 24 feasible solutions.

	Loc. 1	Loc. 2	Loc. 3	Loc. 4
Loc. 1	0	44	54	142
Loc. 2		0	62	140
Loc. 3			0	88
Loc. 4				0

FIG. 6. Distances between Available Locations

It should be noted that the numerical values of the cells were not used in obtaining the solution. Only the cell positions are required to apply this technique of finding the optimal solution.[6]

The method of listing the equipment-location combinations, as they are eliminated from consideration, would quickly become unmanageable as the number of machines is increased. It is therefore necessary to devise another method of recording the undesirable arrangements as they are discarded. Such a method has been developed, but to understand the basis of the method it is first necessary to consider certain properties of the equipment-location combinations.

In an equipment-location problem in which n machines are to be arranged in n different locations, there is a total of $n!$ arrangements possible. Each of the n machines would be associated with each location exactly $(n-1)!$ times. If it could be shown that with any machine placed in a specific location, the remaining $(n-1)$ machines could not be associated with one or more of the other locations, clearly the machine under consideration could not be placed in the specified location. Consider the following cases:

Case I—Assume machine A is given as being placed in location α and that it has been shown that the other $(n-1)$ machines could not be placed in some other location β. In such a situation, it is obvious that machine A cannot be placed in location α.

[6] It should be noted that under certain conditions this minimizing technique may lead to a near optimal solution rather than optimal. It will be proven with the inequation 34 that for the general matrix shown in Figure 1, the northeast corner cell can be used in $(n-1)!$ combinations of the ranked list of $n!$ combinations before any other cell of the matrix. There is no assurance that it will be used in the first $(n-1)!$ combinations. It is possible that various combinations including, as an example, the cells $X_{1,n-1}$ or $X_{2,n}$ might appear in the ranked list prior to the combinations including the cell X_{1n} have been exhausted. It is possible, although unlikely, that the higher valued combinations of cells falling on diagonals closer to the main diagonal may include all of the feasible equipment-location combinations associated with these cells. For this possibility to occur, the numerical difference between the cells appearing on different diagonals would have to be small. This would mean the alternative solutions would have almost the same numerical value. Clearly, as the number of machines under consideration increases, the likelihood of this event occurring decreases.

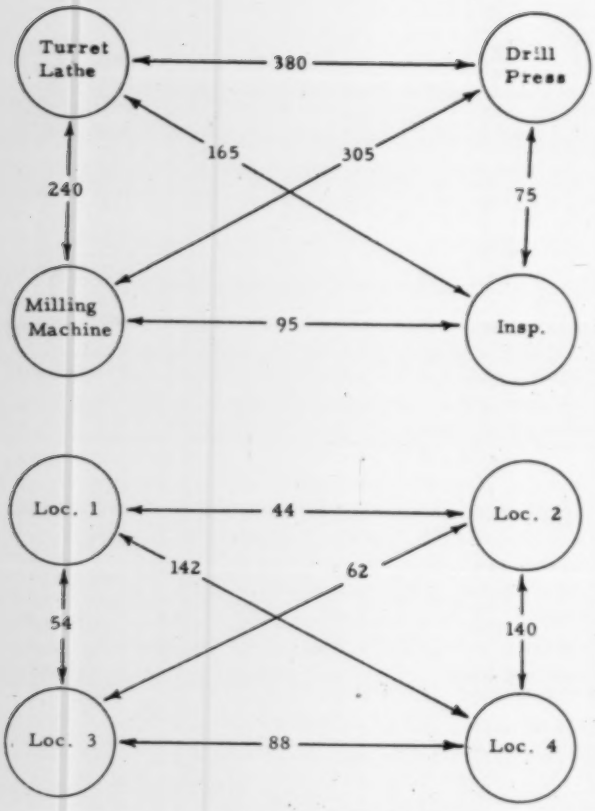

FIG. 7. Graphical Representation of the Equipment-Location Problem

Case II—Assume machine A is given as being placed in location α and it has been shown that all of the remaining machines, except B, cannot be placed in locations β and γ. Machine B could be placed in either location β or γ, but there would be no machine available for the remaining location. It must be concluded that machine A cannot be placed in location α.

Case III—Assume machine A is given as being placed in location α and it has been shown that all of the remaining machines, except machine B and machine C, cannot be placed in locations β, γ, or κ. Machines B and C could be placed in any two of the three locations, but there would be no machine available for the remaining location. It must be concluded that machine A cannot be placed in location α.

The same restricting condition can be developed for the situation in which machine A is given as being placed in location α, and it has been shown that all of the remaining machines, except for $(\phi-1)$ machines, cannot be placed in ϕ locations. Since the number of machines, $(\phi-1)$, is smaller than the number of locations, ϕ, machine A cannot be placed in location α.

In the preceding section, it has been shown for the general equipment-location problem of n machines and n locations, that given one machine fixed in any specified location, then the given machine cannot be placed in the specified location, if it can be shown that $(n-\phi)$ machines cannot be placed in ϕ locations. This basic property of the equipment-location combinations will be utilized in the following tally system of discarding undesirable machine arrangements.

Consider the load-path matrix for the illustrative problem reproduced in Figure 9. The elimination of the northeast corner cell, (*T.L.–D.P.*)—(1–4), has been shown in Eq. 1. to eliminate the following arrangements.

$$\begin{array}{llll} T.L.—1 & D.P.—4 & M.M.—2 & Insp.—3 \\ T.L.—1 & D.P.—4 & M.M.—3 & Insp.—2 \end{array} \quad \text{Eq. 12.}$$

Considering the drill press fixed in location four, the turret lathe could not occupy location one in the minimizing arrangement.

The cell (*T.L.–D.P.*)—(2–4) is among the next group of cells to be eliminated. As indicated in Eq. 2, the following equipment-location combinations are discarded as possible minimizing solutions.

$$\begin{array}{llll} T.L.—2 & D.P.—4 & M.M.—1 & Insp.—3 \\ T.L.—2 & D.P.—4 & M.M.—3 & Insp.—1 \end{array} \quad \text{Eq. 13.}$$

Again considering the drill press fixed in location four, the turret lathe could not occupy location two. Similarly, the discarding of cell (*T.L.–D.P.*)—(3–4) automatically eliminates.

$$\begin{array}{llll} T.L.—3 & D.P.—4 & M.M.—1 & Insp.—2 \\ T.L.—3 & D.P.—4 & M.M.—2 & Insp.—1 \end{array} \quad \text{Eq. 14.}$$

If the drill press is fixed in location four, then clearly the turret lathe cannot be in location three. The elimination of these three cells, also eliminates the possibility of the turret lathe being in three different places when the drill press is in location four. Considering this in the generalized restriction already developed:

$$n = 4 \qquad \phi = 3$$
$$(n - \phi) = (4 - 3) = 1$$

Clearly, the drill press cannot be placed in location four.

		1-2	1-3	2-3	3-4	2-4	1-4
		44	54	62	88	140	142
T.L. - D.P.	380	16,720	20,520	23,560	33,440	53,200	53,960
D.P. - M.M.	305	13,420	16,470	18,910	26,840	42,700	43,310
T.L. - M.M.	240	10,560	12,960	14,880	21,120	33,600	34,080
T.L. - Insp.	165	7,260	8,910	10,230	14,520	23,100	23,430
M.M. - Insp.	95	4,180	5,130	5,890	8,360	13,300	13,490
D.P. - Insp.	75	3,300	4,050	4,650	6,600	10,500	10,650

FIG. 8. Load-Path Matrix—Illustrative Problem

1 - 2	1 - 3	2 - 3	3 - 4	2 - 4	1 - 4	
						T. L. - D. P.
						D. P. - M. M.
						T. L. - M. M.
						T. L. - Insp.
						M. M. - Insp.
						D. P. - Insp.

FIG. 9. Load-Path Matrix

Fixing the turret lathe in location four and applying the same logic, the turret lathe could not be placed in location four. A simple tally system could be used to keep track of these conditions as they arise. Figure 10 shows the first row of the load-path matrix with the appropriate tally marks to one side. The tally marks were generated in the following manner. Every time the loads between the drill press and the turret lathe were associated with the paths between two locations, a tally mark was placed in the drill press and turret lathe row under the two location columns. As an example, when the cell (*T.L.–D.P.*)—(1–4) was eliminated, a mark was placed in the turret lathe row in column one and four. Similar marks were placed in the drill press row. Marks were placed in both the turret lathe row and drill press row in columns two and four, when cell (*T.L.–D.P.*)—(2–4) was eliminated, etc. To understand the significance of the marks, consider only the drill press. A tally mark in column one indicates that, if the drill press had been associated with location one, the turret lathe could not be associated with some other location. A second tally mark in the square would indicate that, if the drill press had been associated with location one, the turret lathe could not be associated with some other location. Since the paths between the different locations never repeat themselves in the load-path matrix, clearly this second mark indicates that the turret lathe has been disassociated with two different locations. A third tally mark in the same square would indicate that, if the drill press had been associated with location one, the turret lathe could not be placed in a third different location. It has been shown that, if the drill press is fixed in location one and the turret lathe could not be associated with three other locations, the drill press could not be in location one. Obviously, three tally marks in any column would indicate that the machine could not be associated with that location. The number of tally marks appearing in this first row location table that would eliminate the machine from any given location can be determined by $(n-\phi)$, where ϕ must have the value of one since only two machines are under consideration. In the example this would be (4–1) or 3 as previously shown.

Figure 11 shows the first two rows of the load-path matrix with the appropriate tally table on the side. The number of tally marks necessary to eliminate the milling machine from any specified location is $(n-\phi)$ where $\phi = 1$. In this example three marks would be sufficient. The same is not true for the third row down, titled drill press. Since the cells in the load-path matrix are being eliminated along diagonal lines, each tally mark in this second drill press row indicates two different machines have been eliminated from some position. As an example, assume the drill press is in location one. The first cell eliminated (*T.L.–D.P.*)—(1–4) would give one tally mark in column one in the first drill press row. The second group of cells eliminated would include (*D.P.–M.M.*)—(1–4). A tally mark would be placed in column one of the second drill press row. This mark would mean, if the drill press is in location one, two machines, turret lathe and milling machine, have been eliminated from position four. The number of tally marks required in this second drill press row to eliminate the drill press from a specific location will be $(n-\phi)$ where ϕ has a value of two, corresponding to the two other machines. In this problem it would be (4–2) or 2. Since none of the loads between machines are ever repeated to the load-path matrix, the number of tally marks required to eliminate any machine from any location could be generalized into the following values.

	No. of tally marks required
First row the machine appears in location matrix	$(n-1)$
Second row the machine appears in location matrix	$(n-2)$
Third row the machine appears in location matrix	$(n-3)$
...	
ith row the machine appears in location matrix	$(n-i)$
$(n-1)$ row the machine appears in location matrix	$[n-(n-1)]=1$

The modification of the load-path matrix shown in Figure 9 into the form shown in Figures 10 and 11 is left up to the reader. To keep track of the various machine-location combinations being eliminated, it is necessary to maintain a simple table as shown in Figure 12. As the combinations are eliminated the appropriate cells are marked out. The end of the eliminations process is reached when only one possible space remains in each row and in each column.

The preceding methodology could be used to determine the best equipment-location combination for problems involving large n's. The load-path matrix becomes large[1] however, as n increases, there are various mechanical means of alleviating this problem. A discussion of these devices is beyond the scope of this paper.

1 - 2	1 - 3	2 - 3	3 - 4	2 - 4	1 - 4			1	2	3	4
						T. L. - D. P.	T. L.	1	1	1	111
							D. P.	1	1	1	111

FIG. 10. First Row of Load-Path Matrix and Tally Chart

[1] The number of rows and columns in the load-path matrix is equal to $n!/2(n-1)!$. Even in a relatively small 50×50 problem, this would mean a 1225×1225 load path matrix.

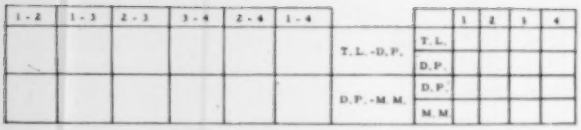

FIG. 11. First Two Rows of Load-Path Matrix and Tally Chart

At this point the mathematical proof of the matrix property will be presented.

EQUIPMENT-LOCATION MATRIX

Considering the sum of exactly nX_{ij} terms, one from each column and each row, of the special matrix shown in Figure 1, we wish to prove that a minimum of $\sum_i \sum_j X_{ij}$ is obtained when $i=j$. Since some X_{ij} terms must be selected in order to satisfy the restrictions of the problem, the smallest X_{ij} will be chosen, X_{1j}. It will be shown that any other $X_{i1}+X_{1j}$ will not be numerically smaller than the value of:

$$X_{11} + X_{ij} \qquad \begin{matrix} i = 2, 3, \cdots, n \\ j = 2, 3, \cdots, n \end{matrix} \qquad \text{Eq. 15.}$$

Let

$$X_{11} + X_{ij} = K_{ij} \qquad \begin{matrix} i = 2, 3, \cdots, n \\ j = 2, 3, \cdots, n \end{matrix} \qquad \text{Eq. 16.}$$

and

$$X_{1j} + X_{i1} = K_{ij}^* \qquad \begin{matrix} i = 2, 3, \cdots, n \\ j = 2, 3, \cdots, n \end{matrix} \qquad \text{Eq. 17.}$$

$$X_{1j} - X_{11} = A_1B_j - A_1B_1 = A_1(B_j - B_1) \qquad \text{Eq. 18.}$$

$$X_{ij} - X_{i1} = A_iB_j - A_iB_1 = A_i(B_j - B_1) \qquad \text{Eq. 19.}$$

but

$$A_1 \geq A_i \qquad \text{Eq. 20.}$$

therefore

$$A_1B_j - A_1B_1 \geq A_iB_j - A_iB_1 \qquad \text{Eq. 21.}$$

and

$$A_iB_1 + A_1B_1 \equiv A_1B_1 + A_iB_1 \qquad \text{Eq. 22.}$$

hence by addition:

$$A_1B_j + A_iB_1 \geq A_1B_1 + A_iB_j \qquad \text{Eq. 23.}$$

but from Eq. 16.

$$A_1B_1 + A_iB_j = K_{ij} \qquad \text{Eq. 24.}$$

and from Eq. 17.

$$A_1B_j + A_iB_1 = K_{ij}^* \qquad \text{Eq. 25.}$$

therefore:

$$K_{ij}^* \geq K_{ij} \qquad \text{Eq. 26.}$$

It has thus been shown that a minimum of $\sum_i \sum_j X_{ij}$ in which exactly n X_{ij} terms, one from each column and each row, is considered, may have the X_{11} term included in it. The selection of any other term in either row one or column one would not reduce the summation value. The selection of this term, X_{11}, would automatically eliminate row one and column one from further consideration because of the restriction of selecting exactly one X_{ij} from each row and column.

The same argument can now be made for X_{22} in the reduced $(n-1)$ $(n-1)$ matrix and so forth until all of the rows and columns are eliminated from consideration. It can thus be seen that a minimum for the $\sum_i \sum_j X_{ij}$ with the stated restrictions, would include the terms along the main diagonal where $i=j$.

It is obvious from the preceding argument that the inclusion of any of the terms falling along the diagonal immediately above the main diagonal, $i=j$, would lead to either the same or a larger numerical value for the summation of the X_{ij} terms.

In the $n \times n$ matrix, there are a total of $n!$ combinations of n X_{ij} terms consistent with the constraint of one X_{ij} from each column and each row. Each term within the matrix will be used in $(n-1)!$ combinations out of the total $n!$ combinations. Let all of the $n!$ combinations be ranked in a nonincreasing order, according to the numerical value of the sum of their respective X_{ij}'s. It will be shown that the first matrix term to be used in $(n-1)!$ combinations of the ranked list will be X_{1n}.

Consider the following four terms: X_{1k}, X_{1n}, X_{mk}, X_{mn}.

where: $m=2, 3, \ldots, n \qquad k=1, 2, \ldots, n-1$

$$X_{1n} - X_{1k} = A_1B_n - A_1B_k = A_1(B_n - B_k) \qquad \text{Eq. 27.}$$

$$X_{mn} - X_{mk} = A_mB_n - A_mB_k = A_m(B_n - B_k) \qquad \text{Eq. 28.}$$

but:

$$A_1 \geq A_m \qquad \text{Eq. 29.}$$

therefore:

$$A_1B_n - A_1B_k \geq A_mB_n - A_mB_k \qquad \text{Eq. 30.}$$

and

$$A_mB_k + A_1B_k \equiv A_1B_k + A_mB_k \qquad \text{Eq. 31.}$$

hence by addition:

$$A_1B_n + A_mB_k \geq A_mB_n + A_1B_k \qquad \text{Eq. 32.}$$

Let λ be defined as follows:

$$\lambda = \sum_i X_{i(j)}$$

$$i = 2, 3, \cdots, m-1, m+1, \cdots, n$$

$$j = 1, 2, \cdots, k-1, k+1, \cdots, n-1 \qquad \text{Eq. 33.}$$

j takes on a unique value for each i.

therefore:

$$X_{1n} + X_{mk} + \lambda \geq X_{mn} + X_{1k} + \lambda \qquad \text{Eq. 34.}$$

Since the restrictions of the problems require one X_{ij} to be selected from row one and one X_{ij} from column n, it is obvious from the inequation 34, that the selection of any

other X_{1k} and X_{mn} when combined with any specified λ, will never give a larger numerical value than obtained when X_{1n} and X_{mk} are combined with the same specified λ. From this it may be concluded that the term X_{1n} will appear first in a total of $(n-1)!$ combinations of the ranked list of $n!$ combinations.

Consider the following four terms: X_{1k}, $X_{1,n-1}$, X_{mk}, $X_{m,n-1}$ where: $m = 2, 3, \ldots, n$, $\quad k = 1, 2, \ldots, n-2, n$

$$X_{1,n-1} - X_{1k} = A_1B_{n-1} - A_1B_k = A_1(B_{n-1} - B_k) \quad \text{Eq. 35.}$$

$$X_{m,n-1} - X_{mk} = A_mB_{n-1} - A_mB_k = A_m(B_{n-1} - B_k) \quad \text{Eq. 36.}$$

but:

$$A_1 \geq A_m \quad \text{Eq. 37.}$$

therefore:

$$A_1B_{n-1} - A_1B_k \geq A_mB_{n-1} - A_mB_k \quad \text{Eq. 38.}$$

and

$$A_mB_k + A_1B_k \equiv A_1B_k + A_mB_k \quad \text{Eq. 39.}$$

hence by addition:

$$A_1B_{n-1} + A_mB_k \geq A_mB_{n-1} + A_1B_k \quad \text{Eq. 40.}$$

Let ϕ be defined as follows:

$$\phi = \sum_i X_{i(j)} \quad \text{Eq. 41.}$$

$i = 2, 3, \cdots, m-1, m+1, \cdots, n$

$j = 1, 2, \cdots, k-1, k+1, \cdots, n-2, n$

j takes on a unique value for each i.

therefore:

$$X_{1,n-1} + X_{mk} + \phi \geq X_{m,n-1} + X_{1k} + \phi \quad \text{Eq. 42.}$$

Since the restrictions of the problem require one X_{ij} to be selected from row one, and the possibility of selecting X_{1n} has been eliminated, it is obvious from the inequation 42 that any combinations including $X_{m,n-1}$ and X_{1m} with any specified ϕ will not have a numerically larger sum than obtained where $X_{1,n-1}$ and X_{mk} are combined with the same specified ϕ. From this it may be concluded that the term $X_{1,n-1}$ will be the second term in row one to appear in $(n-1)!$ combinations of the ranked list of $n!$ combinations. Using the same argument for the remaining terms in row one, it can be shown that the terms falling in a given column of the matrix can always appear $(n-1)!$ times in the ranked list before terms appearing in the columns to their left. The same argument can be made for the other rows in the matrix and it can be concluded that for the terms in any row the terms falling in a given column of the matrix will always appear in $(n-1)!$ combinations of the ranked list before the terms appearing in the columns to their left.

For the sake of brevity, the development of a similar argument pertaining to the matrix column elements will be left to the reader. It can be shown that terms falling toward the top of the matrix in any column, 1 through n, could appear in $(n-1)!$ combinations of the ranked list before the terms falling closer to the bottom of the matrix.

	1	2	3	4
T. L.	Out	Out		Out
D. P.		Out	Out	Out
M. M.	Out		Out	Out
Insp.	Out	Out	Out	

FIG. 12. Machine-Location Table

The above mathematical consideration clearly proves the validity of Figure 2. Although it is impossible to determine the cell's sequence of appearance in the ranked list, the ultimate use of the matrix properties makes this factor unimportant.

CONCLUSION

A technique of minimization of the criterion of interwork area material movement by proper equipment location within the intermittent manufacturing situation has been developed and a simplified example has been solved. A myriad of modifications can be made to account for such factors as different work area requirements for different machines, the separation of incompatible processes, the grouping of similar machines, etc. These modifications are, unfortunately, beyond the scope of this paper. Even in its present form, this methodology provides a completely objective equipment location technique.

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Human Engineering*

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POPULARIZED descriptions of Human Engineering have appeared in a wide variety of technical, trade and scientific publications. Added together and viewed in total, they give the casual reader a very confusing picture of the field. Most authors concede that human engineers do not design humans, but beyond that there seems to be little unanimity.

Depending on the background and interests of a particular author, the human engineer is depicted as a designer of aircraft, automobiles and telephones, a manipulator of men, a dedicated scientist patiently measuring heights and weights to find the average man, a training specialist, a model maker, a writer of instruction manuals, a motivation researcher. Many of these thumb-nail sketches include equipment design and all include psychology. In fact, one would be hard put to find any phase of applied psychology that has not been called human engineering at one time or another.

People within the field have added to the confusion by calling their work psychophysics, biomechanics, experimental psychology, applied psychology, human factors, human engineering, biophysics, biotechnology, engineering psychology and ergonomics. They are found organizationally in groups called Systems Utilization, Reliability, Equipment and Safety, Operations Research, Technical Specialties, Outfitting, Aero-Medical, Personnel and Training, and Industrial Design. They report to anyone from top management to the Manager of Engineering, a design engineer or a project engineer.

As a point of departure for this discussion, the following definition of human engineering will be postulated: the application of the techniques and data of the arts and sciences of psychology, physiology, medicine and anthropology to the problems of man-machine systems design.

HUMAN FACTORS RESEARCH

Beside the area of direct application to equipment design, there is an area of applied research which is unofficially responsible for developing the data used by the human engineer. The work here too is directed toward equipment design but the connection is more remote. The area is coming to be called Human Factors Research and gives rise to some of the confusion in the popular literature noted earlier. Experimental studies of everything from detection thresholds through the effects of extreme environments falls in this area. The work is generally conducted by biological scientists in industry, universities and the military services. Human Factors Research stands behind human engineering in the same manner as applied physics and chemistry stand behind electrical or mechanical engineering.

In practice, it is sometimes difficult to separate the human engineer from the human factors researcher. The two fields fall along a continuum from research to engineering and do not have unions or professional societies outlawing interchange. It is quite common to find individuals recognizing problems while in the process of designing equipment and then following through to a solution by laboratory experimentation. As a matter of fact, many of the people who are actually practicing human engineering today were originally trained as scientists—psychologists, anthropologists, biologists. This tends to make the inherently vague dividing line between applied research and engineering even less distinct. The major part of this paper, however, is concerned with the engineering end of the spectrum, the direct application to design.

ORIGIN AND EARLY YEARS

The typical description of human engineering starts with the work that was done during World War II in the redesign of aircraft and submarine controls and displays. The field certainly blossomed in that era but it is worthwhile to look somewhat beyond that time to see what conditions gave rise to it and how the stage was set for it.

One could argue that human engineering has been practiced ever since the first crude hammer was designed by a prehistoric man. Certainly he considered how he would use the implement and consequently provided it with a handle. But, by the same argument he also practiced mechanical engineering in the process of this design. In any case, fitting the machine to the man was an intuitive and evolutionary process. Good or bad, the intuitive approach generally prevailed until fairly recently.

The work of Taylor, Gilbreth and others in that era comes closest to what we have defined as human engineering. For example, Taylor's classical experiments with the selection of the most efficient shovel illustrate an ap-

*Based upon a presentation to the Industrial Engineering Graduate Seminar, Cornell University, February 13, 1958.

preciation for the importance of matching equipment to the man. But instead of progressing along this path, the application of psychological and physiological data drifted away from equipment design. Instead, it was directed more toward motivation and the selection and training of man to fit the equipment. The fact that the field attracted fakes and phonies who discredited it, undoubtedly had much to do with the failure to develop the approach. Some people, particularly in the field of Industrial Engineering, were aware of the problem and appreciated the approach to solution but they were the exception rather than the rule. Ryan's work is an illustration of the exception in its treatment of the implications of equipment design on operator fatigue (10).

It was not until World War II that the conditions were ripe for a fresh start. Previously, by means of training or experience man had always been able to compensate for the inadequacy in the design of equipment. But military weapons had become very complex and powerful and the unaided human operator could no longer handle them. The only direction open was a redesign of equipment. Psychologists, anthropologists, physiologists and electrical, mechanical and Industrial Engineers worked in design teams, utilizing what they knew of the capabilities and limitations of man to redesign equipment so that it matched his characteristics. The system design concept which began to be formalized about the same time was instrumental in awakening a realization that man was an important part of weapons systems and worthy of design consideration.

The result of these efforts showed significant improvements in the over-all efficiency of the man-machine system, and the field grew. Since that time, specialists in the application of the biological sciences to equipment design have developed and taken their place on the design team with engineers. Effort has been expanded from redesign of equipment to systematic inclusion of consideration of the man from the first phase of the design cycles.

The military services have been instrumental in promoting and developing the field of human engineering. They operate some of the better centers for human engineering (at Wright Field, Training Devices Center, Naval Electronics Laboratory, Naval Research Laboratory, Lackland Air Force Base) and they have motivated industry to follow suit by including human engineering in specifications for weapons systems. This has given rise to some rubber-stamping in order to satisfy contractual obligations but, in general, such practices are easily detected and it has not become a major problem.

The question of whether human engineering represents a separate branch of engineering can be argued loud and long. To the extent that it utilizes a different body of knowledge and has developed some unique techniques, it has a firm foundation for such recognition. Human engineering groups have, in fact, assumed the responsibility for injecting consideration for the human into equipment design. Organized formal training for the field is still lacking and must be provided to insure continuity of this aspect of design. Some hope for the establishment of coordinated course programs is seen in the fact that several universities offer courses in the area as part of their undergraduate engineering programs. At the present time, operating groups are generally doing their own on-the-job training. This is accomplished by forming heterogeneous groups of biological scientists and engineers and waiting for cross-fertilization to take place rather than with any formal training program. The majority of the practicing human engineers are people with training as scientists who have been retreaded to perform what is essentially engineering work. There is a basic inefficiency in this method of preparation which can be avoided by starting with engineers (possibly Industrial Engineers) and supplementing their traditional course work.

MAN-MACHINE SYSTEM DESIGN

In order to illustrate the work of human engineering, two profiles will be drawn of the field. One will be along the system design cycle and the other across the kinds of systems that have been the subject of human engineering design.

The now-familiar system-design concept starts by specifying broad requirements for a system and then progressively refining these requirements in more detail. The objective is optimization of over-all system performance as opposed to suboptimization of component parts. As the requirements are refined, equipment to satisfy them can be specified. The process continues until the smallest component is selected.

In designing a man-machine system, it is convenient to consider the human being as a component of the system. In this sense, he has definable limits and capabilities. With knowledge of his characteristics, the designer can capitalize on his capabilities and avoid or compensate for his limitations. For example, the human is essentially a passive detector and is thus limited in his ability to see objects at great distances. A radar is often used to compensate for this and to extend the operator's "vision." But the human has excellent ability to detect energy in the visible portion of the spectrum. To capitalize on this, the radar energy is transformed to visible light and presented to the operator, usually by means of a cathode ray tube.

The need for consideration of the human in every phase of the design cycle has been demonstrated through experience. The general phases of such consideration are:

1. Selection of the broad functions that the human will perform in the system (e.g., detection, data processing, decision-making, maintenance).
2. Selection of the types of information and control which he will require in order to perform the assigned functions (e.g., information about his position, the presence of targets, the

time of day, etc., and control over starting, firing, maneuvering, etc.).

3. Detailed specifications of the controls, displays and auxiliary equipment (e.g., console layout, control size, room lighting, display brightness, oxygen supply, control movement, etc.).

The phases will be discussed one at a time to illustrate the level of design decisions involved and the techniques used to make them. It should be recognized, however, that the breakdown by phases is done primarily for expository purposes. In practice they overlap each other and decisions made in one phase may be reviewed and altered later. Further, decisions made by the human engineer inevitably affect other parts of the system and so cannot be made solely on the basis of consideration of the human elements. The human engineering considerations are part of a larger system design effort.

PHASE 1—HUMAN FUNCTIONS

Given a broad statement of the purpose of the system and the environment in which it operates, the human engineer's job is to choose the functions which the man should perform. As a first step the requirements must be refined and translated into specific functions that must be performed within the system. If the system is an aircraft, for example, a mission profile is drawn, i.e., the various phases of the mission plotted against time with the functions that the system will perform and a description of the environment keyed to the time axis. The formality of the refinement process depends on the complexity of the system. In the case of the aircraft, the mission profile is a very formal and detailed document. The environment must be examined to insure that it is suitable for the operator and his potential contribution to system performance must be assessed.

The initial decision, of course, is whether or not to have a man in the system. A great deal of human factors research has been and is being performed to determine physiological limits of the human with respect to temperature, pressure, radition, G-forces, oxygen, etc. The literature will generally yield sufficient information to determine whether a particular environment will be dangerous for a human or will degrade his performance. One area where the literature is currently deficient is in the effects of space travel on the human. A number of large scale physiological and psychological studies are in progress to fill the void. If the raw environment is found to be unsatisfactory the human engineer must either eliminate the man or supply an artificial environment. The artificial environment might take the form of a pressurized cockpit, an oxygen mask, a G-suit, an air conditioned room or a lead-lined enclosure, depending on the particular conditions.

Satisfied that the human can function effectively in the raw or artificial environment, the question still remains as to whether he will add anything to the system and, if so, in what capacity. General guide lines to aid in evaluating the relative efficiencies of men and machines in performance of various functions have been constructed and are of some help in the early stages. It must be recognized however that these are used as guides and are not intended to be a do-it-yourself kit. The following listing is adapted from (12) and represents a summary of recommendations of a number of authors.

Humans are relatively superior to machines, in terms of our present understanding of human and equipment capabilities, with respect to the following:

1. Ability to handle unexpected events—machine must be explicitly programmed.
2. Ability to use perceptual constancies (e.g., to recognize objects and places despite varying conditions of perception).
3. Ability to use sequential dependencies in the real world (i.e., profit from experience).
4. Sensitivity to a wide variety of stimuli (heat, light, sound, pressure, etc.); range of sensitivity, however is restricted.
5. Originality in putting to use incidental intelligence picked up over a period of time.
6. Detecting signals in an overlapping noise spectrum (e.g., detection of radar signals through jamming).
7. Capability for improvising and adopting flexible procedures (e.g., can reprogram easily and quickly; can vary performance tolerances readily).
8. Capability for acting as a servo with a wide variety of modes (e.g., linear amplifier, integrator, etc.).
9. Capability to perform under some conditions of overload and ability to select own inputs.
10. Ability to reason inductively (i.e., to make generalizations from specific observations).

Humans are poor, with respect to machines, for the following:

1. Monitoring other men or machines.
2. Exerting large amounts of force smoothly and precisely.
3. Performing routine, repetitive tasks. (Human becomes bored, fatigued, careless.)
4. Rapid computing and handling large amounts of stored information.
5. Ability to reason deductively (i.e., to use rules for processing information).
6. Responding quickly to control signals.

Man is generally excluded from the performance of certain functions where conditions are likely to result in human errors:

1. Perceptual requirements which are beyond or near physiological limits or which conflict with established habit patterns.
2. Response requirements which are physically difficult, conflict with established habit patterns or which cannot be readily checked or monitored for their adequacy (e.g., the application of extreme physical force).
3. Decisions which require undue reliance on memory, must be preceded by extensive organization of information or must be accomplished in too short a time in view of other necessary activities.
4. Communication requirements which interfere with other activities.
5. Tasks which overload the human, which result in inadequate work load distribution with respect to time or do not permit adequate or timely monitoring of the general situation.

These general comparisons must be viewed critically when the time comes for applying them to a specific situation. They were arrived at by comparing man with some sort of generalized method of implementing the particular function. However, when the human engineer, in conjunction with the rest of the system design team, has to make the judgment as to whether a man or a machine is to be used for a specific function he must make the comparison between a man and specific alternate methods of implementation.

The detection of radar signals in noise or jamming is a case in point. The general recommendation given above indicates that man is superior to machines for this task. His relative superiority, however, is a function of the characteristics of the signal, of the noise background and of the equipment he is given. The gap between the human and automatic detection devices is being closed and the choice between them must be evaluated carefully. The designer must often turn to experimentation with realistic simulation to provide a basis for the decision.

In practice, the situation rarely exists where the human engineer can sit down in isolation, assign the human the most appropriate functions and drop the matter. Compromises must be made with the ideal allocation in the interests of over-all system performance. For example, it may be economically or technically impractical to mechanize a transformation of coordinates within the space available. In spite of the human's inferiority in deductive reasoning the operator may have to perform the function. Fortunately, the state of the art in computers and storage mechanisms is approaching the point where a choice of alternatives is often available and the man can look for some relief from being assigned tasks in desperation.

But this is not universally true at present and the operator is still called on to fill the gaps. Man is naturally very flexible and will be used whenever a function cannot be implemented in any other way or when all the contingencies cannot be anticipated. This flexibility and adaptability is often the man's prime contribution to the system.

PHASE 2—DISPLAY AND CONTROL FUNCTIONAL DESIGN

With the over-all system outlined and functions assigned to the man, the human engineer examines the man-functions in more detail, breaking them into subfunctions and tasks. Analyzing them first individually and then collectively, he determines the responses or actions which the operator must perform, the decisions he must make prior to performing them and the information required to make the decision.

As in Phase 1, the techniques employed here depend on the complexity of the system. As a minimum, the tasks are set down in a table and the corresponding responses and information requirements listed. For more complex systems elaborate charts and graphs are used. Many of the graphical techniques of time and motion study have been adapted for this purpose. Time is often used as a base dimension with the information, decisions and actions keyed to it in overlay form. Typical sequences may be run through on paper as a check on the completeness of the analysis.

As an illustration, a function often assigned to the human is to take over some normally-automatic function in the event of a malfunction. One of the tasks within this function is to recognize that a malfunction exists and assume control. To accomplish this task the operator must be supplied with information concerning the operation of the automatic element (at least whether or not it is operating satisfactorily) and a means of switching control to himself.

When this is done for all of the man-functions, the designer reviews his analysis. He notes repetition of information and response requirements and the possibility of combining tasks and functions or even eliminating some. He works closely with engineers responsible for other elements in the system, reviewing earlier joint decisions made with regard to the basic division of responsibility between man and machine.

During this phase the human engineer carries the design one step further by specifying:

1. The types of controls that the operator will require to communicate with the machine.
2. The types of displays that will be provided to supply information to the operator.

With respect to the controls, he considers:

1. Whether it should be continuous or discrete (e.g., a push-button or tuning knob).
2. Whether it should be directly connected to the controlled object or "aided."
3. The possibility of combining controls.
4. The necessity for shape, size, color or location coding.
5. Whether hand or foot controls are to be used.
6. Approximate preferred locations.

With respect to the information to be displayed, he considers:

1. Whether it should be quantitative or qualitative.
2. Whether it should be continuous or discrete.
3. The precision required.
4. The data rate.
5. The type of stimulus to be used (visual, auditory, etc.).
6. The frame of reference in which it should be presented.
7. Whether it should be associated with other information.
8. Whether it is to be used for more than one task.
9. Whether it should be continuously displayed or displayed only on demand.
10. Whether information can be combined on a single display.

While the considerations of controls and displays are separated for the purpose of discussion, it should be recognized that the relation between them is critical. The designer is careful to insure that they are compatible and will not require the operator to perform complex mental transformations. He looks for a unifying principle which

will tie the display and controls together. Numerous examples of such principles have been used successfully. For example, the controls and displays might be laid out in their order of use, so that the operator simply follows down the line. This is especially appropriate in a check-out procedure or a missile count-down where one step must be completed before proceeding to the next. Another approach is to have all of the displays and controls associated with a particular part of the system arranged together. Thus radar displays and controls might be kept together, and separated from computer displays and controls. On the other hand all of the displays might be put in one area and all of the controls in another and the relation between them might be indicated by shape or color coding. A large number of arrangements is possible and experimentation might be required to select the most efficient for the particular combination of functions.

At this stage of development a functional mock-up is often constructed to aid in combining the displays and controls. It also serves as a first step in the layout of the operator's work place. A rough shell of preferred areas can be constructed based on anthropometric data from the literature. Since the detailed configuration of the displays and controls has not yet been specified, the "displays and controls" might simply be word descriptions.

PHASE 3—DETAILED EQUIPMENT DESIGN

The design cycle now closes on the detailed design of the equipment which the operator will use. For purposes of discussion the problems which arise can be roughly divided into the following areas: Environment, Workplace, Controls and Displays.

Environment

Although man is capable of adapting himself to a wide range of environmental conditions, his efficiency is often impaired by even slight variations from normal conditions. The human engineer attempts to duplicate the ideal conditions or, if this is impossible or impractical, estimates and compensates for the reduction in operating efficiency. He might supply oxygen, cool, heat or pressurize the work area, provide protection from radiation or outfit the operator with special clothing. A great deal of work has been done lately, for example, in the design of flight suits to protect the pilot from the environment at high altitude.

One would think that at least gross consideration of operator comfort would be included in every equipment design. It is far from universal however and operators are still found sitting on top of hot electronic equipment or supplied with contaminated air.

Workplace

Anthropometric data is available in abundance in the literature (6) (7). From it, the human engineer can obtain or derive optimum and limiting dimensions for a wide variety of operator positions—standing, sitting, supine, prone, strapped in place, etc.

As was noted, earlier, a full size mockup of the operator's compartment is usually constructed and the functional display and control areas selected. The rest of the design process will revolve around this mockup and it must be checked to insure that:

1. It conforms to the space allowance.
2. Control areas can be reached easily.
3. Display areas can be seen.
4. Overhead or external illumination is sufficient for the type of work that is being performed and that it does not cause glare or interfere with displays.
5. The work place will accommodate a range of size of operators (not just the "average" man).

Literally whole books have been written covering these considerations in detail. Reference (5), for example (235 pages) is concerned solely with the space requirements of the seated operator. A great deal of experimental work and volumes of reports are devoted to illumination problems (1). Similarly, preferred reach areas and display areas have been plotted (6).

Displays and Controls

The displays and controls represent the operator's means of communication with the rest of the system. Through the displays he receives information about the system, the external environment and the results of his control movements. He makes decisions based on this information and takes action by manipulating the controls.

Having previously arrived at some unifying principle for designing and arranging the controls the designer sets about implementing it. It is difficult to generalize about this detail design of the hardware. Attempts have been made in this direction, but they have not been universally successful. The difficulty lies in the large number of variables that affect the efficiency of the design. Even in simple cases an apparently insignificant change in one variable can make a particular recommendation invalid. Consider the problem of rigorously specifying what the direction of a control movement should be. One set of recommendations can be derived from what are called population stereotypes. For example, people prefer, and expect, "up," "forward," "right" and "clockwise" movements to turn something on or to increase it. However, where there is direct feedback from the object being controlled as in driving an automobile or feedback through the movement of a display as in positioning a marker on a cathode ray tube, the population stereotype rules may lead to errors. The effect of feedback is often more subtle than indicated on these examples and a design decision has to be made as to which is the overriding consideration—feedback or stereotype.

Undoubtedly this situation will improve with time and human engineering cookbooks will be available for more general application. To be of real value, however, these

books must make explicit:

1. An estimate of the validity of the recommendations.
2. The limitations within which the recommendations are valid.
3. The consequences of violating the recommendations in terms of loss of efficiency, increased time, increased fatigue, etc.

As an illustration, consider the problem of selecting a control to be used for positioning a marker on a target which will appear on a cathode ray tube. The variables are the size of the tube, the precision required, the size, brightness, and expected movement of the target, the frequency of the task and the length of time the marker must be kept on the target. The designer must select the type of control that will be used, i.e., a joystick, knobs, bowling ball, pantograph. He must then specify the ratio between control movement and marker movement, the static and dynamic friction to be built in, the size, the position with respect to the display and with respect to other controls, whether the control will position the marker directly or adjust its velocity or acceleration, whether the display will be "quickened" (i.e., the predicted result of a display movement shown immediately). Much research has been done in this area but still more is required before rigorous general design recommendations can be made. Along with this, we must gain a better understanding of precisely how a man operates in such a control loop.

All of the control and display design problems are not this involved and a number of excellent reports (1) (4) (13) have compiled information useful to the designer. But there is much still to be done.

APPLICATIONS OF HUMAN ENGINEERING

In order to illustrate the scope of human engineering, brief descriptions of areas that have been the subject of human engineering consideration will be presented.

There has been no attempt to be exhaustive but simply to give examples. The interested reader can find amplification in the literature.

AIRCRAFT COCKPITS

The high performance military aircraft has been one of the most dramatic and most challenging systems to come under human engineering consideration. In fact, the problems arising from manned flight at high speeds and altitudes are the ones that gave rise to human engineering.

In twenty-five years, the aircraft designers have increased the speed of their planes from less than 100 mph to over 1000 mph. During the same period, the design of the displays and controls for the pilot have, at best, remained the same. The higher performance of modern planes has left the pilot with little time for decision and little room for error in execution. The limitation on the combat performance of the aircraft often lies in the pilot rather than in the aircraft itself.

A number of attacks have been made on the problem. The approaches range from a simple regrouping and standardization of instruments, through redesign of specific instruments, to a basic redesign of the entire cockpit. The latter approach serves as a good illustration of the complete design cycle which was explained earlier. From an exhaustive listing of the information requirements, a completely new display system has been developed. Such a design cycle is long and expensive. After five years of work the system is only now being evaluated on flight simulators.

A word about simulators is in order here since they are used extensively by human engineers, especially in the aircraft industry. The cost of real flights and the inherent dangers involved make realistic simulation worthwhile for preliminary evaluation and for training. From the first pneumatic Link Trainers, flight simulators have evolved into elaborate analog computers which give very realistic simulation of actual flight. The use of mechanical, optical and electronic simulators has extended into other areas and they have proven to be valuable tools for the human engineer.

COMBAT INTELLIGENCE CENTERS

All of the military services maintain Combat Intelligence Centers (CIC) in one form or another. They serve as nerve centers for combat operations where information is gathered, correlated and processed, tactical decisions are made and control actions taken. Whether located on an airplane, a submarine, a tank, a surface ship or in a bunker, they perform essentially these same functions. Human operators within the CIC's may perform any or all of the functions although the modern CIC is generally highly mechanized. In any case, the tactical decisions are usually left for the human.

The human engineer finds design problems in CIC's that run the full range of his interests, from the broad system design to the knobs and dials. Even if decision-making is the only man-function in the system, the communication links between man and machine (controls and displays) are critical. As the decision-maker the man is in series with the other components of the system. Error or delay on his part affects the efficiency of the system directly. Accordingly, a great deal of experimental and design effort has gone into information coding for efficient communication from machine to man. Similarly, the flow of command information to the machine is facilitated by the design of appropriate controls.

In addition to these, there are the problems of workplace layout, illumination, environment, maintenance, etc. A problem that has not been mentioned earlier is the interrelation between men in the system. Most CIC's involve more than one man, some of them as many as fifty. Early in the design cycle, functions must be distributed among the various operators to form an efficient team. Communication facilities must be provided between the men.

SPACE FLIGHT

Recent developments in the missile and rocket field have made manned space flight a realistic possibility in the near future. The more optimistic commentators are predicting such flights within the next two or three years. But space travel will be very demanding of the human. He will have to endure extreme G-forces, be exposed to high radiation levels, live in isolation for long periods in cramped quarters and experience weightlessness.

A number of large scale experimental programs are underway to determine man's ability to withstand the rigors of space flight and to specify the design requirements for artificial environment. Short periods of weightlessness have been achieved in conventional aircraft while performing parabolic outside loops. Centrifuges and rocket sleds have been used to test the effects of high G-forces. Elaborate simulators are in use to study the psychological effects of isolation for long periods of time. Balloon flights have been made to extreme altitudes. Soon a rocket ship will propel humans to the outer fringes of the atmosphere. Since it will probably be impractical to maintain sea-level pressure in a space vehicle, tests are being conducted to determine the highest equivalent altitude man can tolerate.

Strictly speaking, these studies fall in the area which we have defined as Human Factors Research.

As space flight approaches reality, human engineers are already becoming concerned with the role man will play. There is the question, for example, of whether he should be rendered unconscious during part of the flight in order to conserve his energy, letting automatic controls launch the vehicle and navigate. The same basic questions of the allocation of functions must be answered, but against the background of an entirely new and largely unknown environment.

INDUSTRIAL AND COMMERCIAL APPLICATIONS

The primary applications of human engineering have been to military systems. Many human engineers are hired by industry but they are working on military problems. There are exceptions, of course, notably at Bell Telephone Laboratories and the Cornell Aeronautical Laboratory.

The telephone has been the subject of a long term design program at BTL and the program has become something of a standard in the industry. The weight and dimensions of the handset have undergone extensive testing and redesign, as have the dial mechanisms. It was found, for example, that the simple addition of a white dot in the finger holes reduced dialing time about 0.7 seconds. Push buttons and tumbler mechanisms are under study as substitutes for the present dial.

The CAL studies have led to major automobile design recommendations. The major emphasis has been on the reduction of injuries resulting from accidents. Design recommendations have included safety belts, padded interior surfaces and improved control mechanisms. Some of these have found their way into the design of our automobiles, when they did not interfere with the plans of the Detroit stylists.

Widespread infiltration of industrial and commercial design processes will have to await a motivating force similar to the one that arose in the military. That is, it's going to have to be worthwhile to design equipment around the man. It should be noted that it was worthwhile in the case of the telephone redesign, with the unit saving in dialing time resulting in significant aggregate savings. In the case of the automobile, the potential reduction in traffic fatalities is well worth the design effort, not to mention the effect on sales.

The age of automation at first appears to relieve the need for considering the man in designing equipment. The fact is, however, that exactly the opposite is true. When the man does appear in the automated system, as a monitor, a programmer, or a maintenance man, he can easily become the limiting component. Failure of the man to function properly because the equipment is not compatible with his characteristics will mean failure, or at least inefficiency, of expensive automated equipment. Designing the equipment around him thus becomes worthwhile, and automation may serve as the impetus to increased application of human engineering in industry.

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Determination of Optimum Sizes and Economic Feasibility of Shipping Containers Using Operations Analysis Techniques*

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THE containerization of general cargo represents the most promising innovation in the worldwide shipping industry. The high costs of loading and unloading ships have focused attention on the critical need for developing more effective handling methods. The shipping containers referred to in this research effort are not to be confused with boxes used merely to package commodities for shipment. Containers are large boxes (at least 100 cubic feet in capacity) made of different materials and sturdy enough to be re-usable. Their principal functions are to consolidate dry general cargo items destined for one consignee, to speed movement by reducing cargo handling, and to protect shipments from damage and pilferage while enroute.

This paper (1) reports in brief on the research efforts which have resulted in the development of methodologies for determining:

1. The optimum sizes of shipping containers; this phase of the study included a unique application of a high-speed digital computer using simulation techniques in order to determine how different size commodity packages fit into different size containers.
2. The economic feasibility of containerization over palletization.

INTRODUCTION

Commodities now being transported by ship, rail, air and road are highly heterogeneous with respect to size, shape, density, etc.. Therefore highly flexible but also highly inefficient handling systems must be used to move general cargo. Since cargo ships are designed for flexibility or, in other words, to accommodate a wide variety of commodities, the opportunities for the use of mechanical loading methods such as conveyors are limited. Conveyors and automatic equipment are used extensively on specially designed ships for the handling of bulk commodities, such as coal, ore, grain, bananas, etc. High handling rates of 2000 to 3000 tons per hour have been achieved by designing special ships, special cargo transfer equipment and special terminals. This can be contrasted to the rate of handling general cargo which is approximately 10-20 tons per hour per hatch or a maximum of 50-100 tons per hour if all five hatches on a cargo ship are loaded simultaneously.

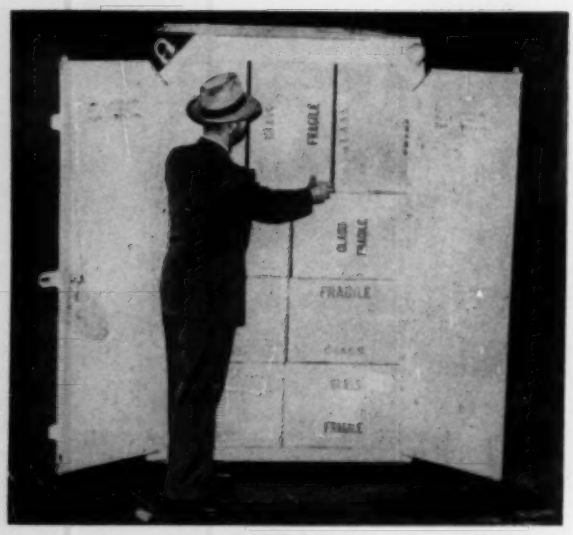
A ship earns no revenue while it is tied up to a berth. The average ship has a fixed cost of $2000 to $3000 per day while in port. Revenue results from charges on the transportation of goods by water—not for storage on shipboard at dockside. In the event of war, the extremely heavy demands on shipping and the easy targets which tied-up ships provide are two additional reasons for reducing the "turn-around time" or the time that a ship is in port.

The use of shipping containers results in the homogenization of general cargo, thereby reducing the large variability introduced into the present cargo handling system by the commodity component. The container shown in Figure 1 is typical of those in current use by shipping companies.

"STATE OF THE ART"

In January 1955, a direct mail survey was initiated regarding the use of containers in water, land, and air transportation networks. One hundred and six letters were sent to shipping companies, educators, military installations, and manufacturers throughout the United States and several foreign countries. Seventy responses provided a wealth of information which, supplemented by a library search and numerous visits to shipping companies in the Los Angeles and San Francisco areas, gave

* This paper is based on research sponsored by the Office of Naval Research, U. S. Department of the Navy and the Maritime Administration, U. S. Department of Commerce. The Complete research effort on Containerization is reported in the Monograph: Carrabino, Joseph D., "An Engineering Analysis of Cargo Handling—VI; Containerization," Report 57-56, Department of Engineering, University of California, Los Angeles, July 1957, 200 p.



DIMENSIONS	INSIDE	OUTSIDE
HEIGHT	6'0"	6'6"
DEPTH	6'0"	6'2"
WIDTH	4'0"	4'3"

FIG. 1. Typical Container in Current Use

a comprehensive picture of the "state of the art" of containerization. These preliminary efforts led to the following consensus:

1. The problem of the determination of the optimum size or sizes of shipping containers appeared to be a crucial one. There seemed to be no agreement whatsoever on this problem.
2. Likewise, there appeared to be a lack of agreement on the problem of how to determine the economic feasibility of containerization over conventional methods of handling, such as palletization. The Neac Study (6) represents an initial effort in this direction.
3. The Army (3), Navy, and Air Force have already spent large sums of money experimenting with containers.
4. European countries (3) have progressed much further than the United States along the road to containerization. An International Container Bureau has been established since 1945 with headquarters in Paris.
5. The inadequacy of present cargo ships for carrying containers is recognized. Much serious thought is already being given to designing container ships.
6. In summary, it can be said that containerization represents the "hottest" current innovation in the shipping industry. The implications are numerous and staggering.

ADVANTAGES AND DISADVANTAGES

The *advantages* claimed for containers can be summarized as follows (all are not mutually exclusive):

1. Speed up the loading and unloading of all types of transport: rail, ship, air, road, thereby reducing the "turn-around time."
2. Protect against pilferage.
3. Protect against damage to commodities.
4. Lower insurance rates will result.
5. Cheaper packaging may be used for the commodities carried.
6. Should reduce the documentation required enroute.
7. Reduce the number of handlings of individual packages.
8. May be used at destination for temporary storage, housing, and offices.
9. Modification of the external characteristics of cargo for easier handling.
10. Customs checking should be easier, especially at European borders.
11. From a military standpoint there is a reduction in the volume of shipping required because of the minimization of losses from damage, pilferage, and enemy action.
12. From labor's viewpoint containers could be attractive because men could be working, loading and unloading containers even though ships are not in port, thereby levelling peak work loads and stabilizing employment.
13. Ideal for handling passengers' baggage.
14. Ideal for handling mail.
15. Provide covered storage in open areas, thereby protecting commodities against elements.
16. Will have sales appeal to shippers, thereby giving a competitive advantage to transportation companies providing them.

The *disadvantages* claimed for containers can be summarized as follows:

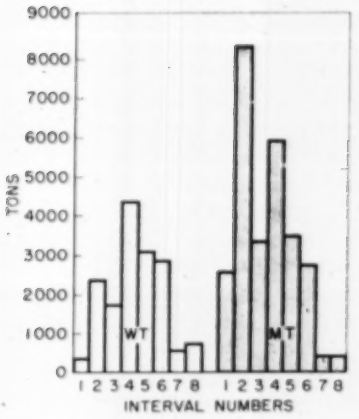
1. Cost of containers.
2. Tare weight of containers.
3. Loss of cubage in the containers, and in the carrier used to transport containers.
4. Cost of returning empties.
5. Difficulty of man-handling requires heavy gear.
6. Institutional difficulties, i.e., labor practices.
7. Accountability for containers.
8. Rail rates in the United States are presently based on highest rated commodities in the containers.

SCOPE OF RESEARCH EFFORT AND MODE OF ANALYSIS

After considering the many problems posed by containerization which might yield to engineering modes of analysis, the decision was made to place the main focus of the research effort on the crucial need for the development of methodologies for:

1. Determining the optimum sizes of shipping containers.
2. Determining the economic feasibility of containerization over palletization.

An empirical approach using operations analysis techniques was employed. Arrangements were made with the American President Lines in San Francisco to use actual performance data for all commodities which were shipped over a typical trade route by two sister ships on eight consecutive voyages. A voyage consisted of the round trip of a vessel from home port to home port (San Francisco). The sequence of ports of calls on this Trans-Pacific Trade Route is shown on Figure 5. Each of the two ships analyzed makes eight voyages a year. Therefore, the data utilized represent six months of operations for each ship or the equivalent of one year for one ship.



KEY

INTERVAL NUMBER	DENSITY* INTERVAL LB/FT³	STOWAGE FACTOR INTERVAL FT³/LONG TON
1	1 – 99	2240 – 226.3
2	10 – 199	224.0 – 112.6
3	20 – 299	112.0 – 74.9
4	30 – 399	74.7 – 56.1
5	40 – 499	56.0 – 44.9
6	50 – 599	44.8 – 37.4
7	60 – 699	37.3 – 32.05
8	GREATER THAN 70	LESS THAN 32.0

NOTE:

1. LONG TON = 2240 LB
   WEIGHT TON (WT) = 2000 LB
   MEASUREMENT (MT) = 40 FT³
2. $\text{DENSITY} = \frac{\text{WEIGHT}}{\text{VOLUME}} = \frac{\text{WT} \times 2000 \text{ LB}}{\text{MT} \times 40 \text{ FT}^3} = \frac{\text{WT}}{\text{MT}} \times 50 \frac{\text{LB}}{\text{FT}^3}$
3. $\text{DENSITY} \left(\frac{\text{LB}}{\text{FT}^3}\right) \times \text{STOWAGE FACTOR} \left(\frac{\text{FT}^3}{\text{LONG TON}}\right) = \text{CONSTANT} = 2240 \frac{\text{LB}}{\text{LONG TON}}$

FIG. 2. Totals for 8 Voyages—4 each for S.S. *President Wilson* and S.S. *President Cleveland*.

DOMINANT VARIABLES AFFECTING SIZES

The dominant variables affecting the sizes of containers which were investigated in this study are:

1. The weight ton and measurement ton distributions of all physically containerizable commodities for different density and stowage factor intervals; here a large number of histograms were developed. (For definitions of these terms, see KEY next to Figure 2.)
2. The fit of different size packages into different size containers; here a unique application on a high-speed digital computer was made using simulation techniques.
3. The fit of different size containers into all the storage compartments of the two ships; here scaled layouts were used.
4. The influence of truck and railroad-car sizes; information was obtained from field trips.

A description of the analysis of each of these variables reported in subsequent sections of this paper is followed by a discussion of their inter-relationships under varying circumstances in which containers might be used.

DENSITY DISTRIBUTIONS OF COMMODITIES

The data for the eight voyages which were tabulated on IBM machines included a total of 1366 different commodities. For each commodity the following information was included: voyage number, port of loading, port of discharge, revenue dollars earned, weight tons, measurement tons, density and stowage factor. These data were grouped together for like commodities. Since not all of the 1366 commodities shipped were suitable for containerization, it was necessary to develop criteria for selecting those which might be physically containerizable (1). It was found that 861 commodities or 63% of the total met these criteria. These 63% of the total commodities represented 48% of the total revenue earned.

It seems to be the universal practice among operating personnel in the shipping industry to never lift more than three tons or 6000 pounds on a ship's boom (rated at five tons) without special rigging. This rule of thumb is adhered to tenaciously in order to minimize accident hazards. Therefore, since the weight of a load is fixed at this upper limit, it is essential to know the range of densities of commodities to be handled in order to determine the desirable volume ranges of containers.

Figure 2 shows the distribution of weight and measurement ton totals for eight voyages of all physically containerizable commodities for different density and stowage factor intervals. The bi-modal nature of these distributions is suggestive of a two-size container system for this trade route. The author will comment on this point later in the paper. Similar histograms were developed for each of the four voyages of each ship, Figures

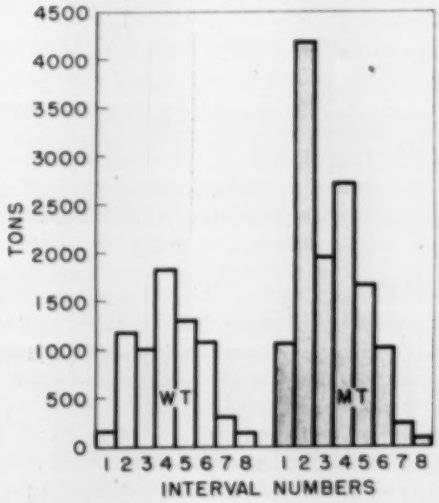


FIG. 3 Totals for 4 Voyages—S.S. *President Cleveland*

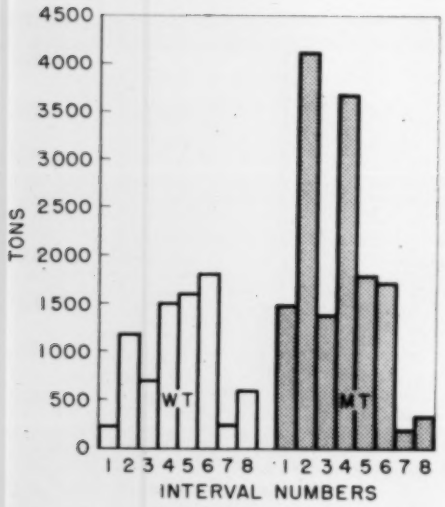


FIG. 4. Totals for 4 Voyages—S.S. *President Wilson*

3 and 4, and for each of the eight voyages (1).

The intent in developing Figure 5 was to visualize the distribution of containerizable loads taken aboard at each port of call in the trade route. This information is essential to the determination of the number of containers needed to service the trade route. The unequal load distribution highlights the problem of maintaining an even flow of containers, establishing appropriate collection centers or banks, etc. This is a sophisticated problem which is currently being investigated by the Cargo Handling Research Project at U.C.L.A.

SIMULATION STUDY

One of the disadvantages associated with containerization is the loss of cubage in the container because of the impossibility of achieving perfect stowage of different size packages in a given size container. In order to appraise the magnitude of this loss, a simulation technique on the SWAC High-Speed Digital Computer at U.C.L.A. was employed. The objective of this technique was to determine what the internal cubic loss would be in different size containers for packages of different sizes.

The problem of selecting the commodities to be used for this analysis was a formidable one. Data on the height, depth, and width of commodity packages were obtained after much effort which was replete with frustration and disappointments. Because of the cost of these data, it was necessary to resort to sampling procedures. It was found that 8.6% of all the physically containerizable commodities accounted for 64.1% of the revenue earned by these commodities.

The program developed for the SWAC Computer achieved a very high degree of simulation of actual loading patterns used by longshoremen. The initial assumption was that only one size package would be loaded into a given container. There are six initial feasible orientations of a package in a container if the package contains a commodity which does not restrict the position of the package. These are shown on Figure 6. If, for example, a package contains glassware and must be loaded "this side up," then the position of the package is restricted and only loading patterns Nos. 1 and 2 apply. (See Figure 6). The input data into the computer consisted of 54 different package sizes and 49 different container sizes.

The intent in Figure 7 is to show the "rule of fit" or variation in the internal cubic losses of containers of increasing volume when loaded fully with packages of different sizes. It was initially thought that for a given size package the losses would decrease as container sizes increased. However, it was most interesting to discover that the loss variation was periodic-like.

Many other analyses were made in this phase of the study which yielded results of particular interest to the packaging industry. However, because of space limita-

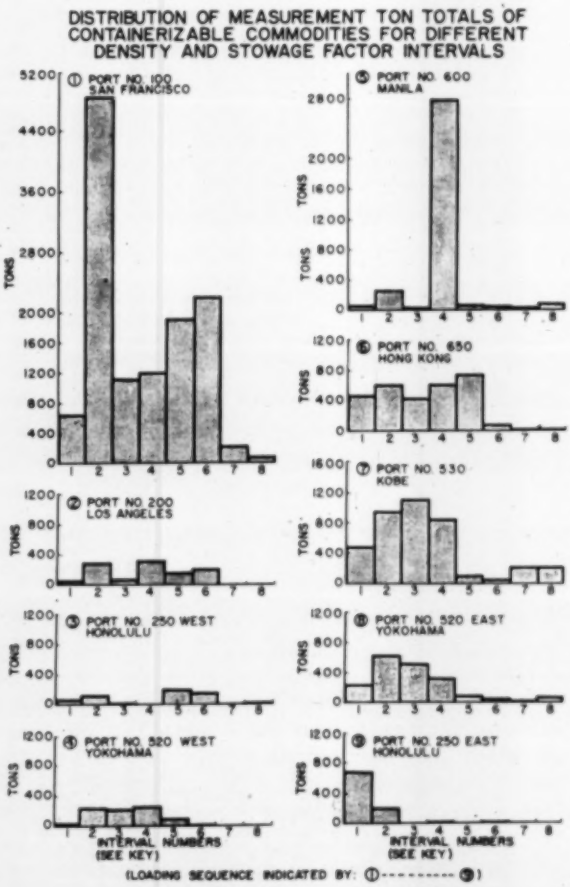

DISTRIBUTION OF MEASUREMENT TON TOTALS OF CONTAINERIZABLE COMMODITIES FOR DIFFERENT DENSITY AND STOWAGE FACTOR INTERVALS
① PORT NO. 100 SAN FRANCISCO
⑤ PORT NO. 600 MANILA
⑥ PORT NO. 650 HONG KONG
⑦ PORT NO. 530 KOBE
② PORT NO. 200 LOS ANGELES
③ PORT NO. 250 WEST HONOLULU
⑩ PORT NO. 520 EAST YOKOHAMA
④ PORT NO. 520 WEST YOKOHAMA
⑨ PORT NO. 250 EAST HONOLULU
TONS
INTERVAL NUMBERS (SEE KEY)
(LOADING SEQUENCE INDICATED BY: ①---------⑨)

FIG. 5. Loads Taken Aboard at Ports of Call for 8 Voyages—4 each for S.S. *President Cleveland* and S.S. *President Wilson*

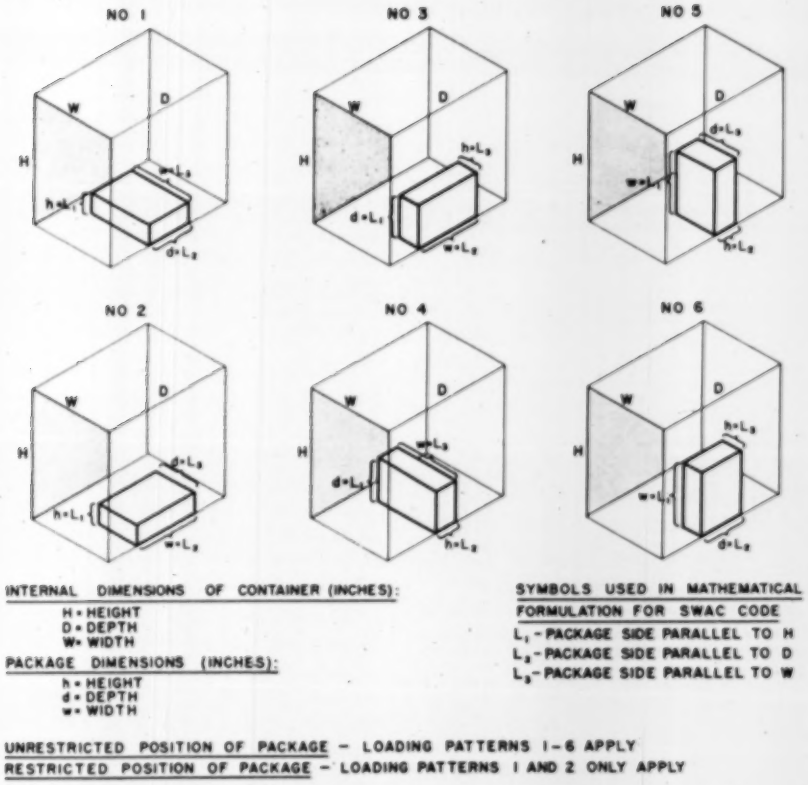

NO 1
NO 3
NO 5
NO 2
NO 4
NO 6
INTERNAL DIMENSIONS OF CONTAINER (INCHES):
H = HEIGHT
D = DEPTH
W = WIDTH
PACKAGE DIMENSIONS (INCHES):
h = HEIGHT
d = DEPTH
w = WIDTH
SYMBOLS USED IN MATHEMATICAL FORMULATION FOR SWAC CODE
L_1 - PACKAGE SIDE PARALLEL TO H
L_2 - PACKAGE SIDE PARALLEL TO D
L_3 - PACKAGE SIDE PARALLEL TO W
UNRESTRICTED POSITION OF PACKAGE - LOADING PATTERNS 1-6 APPLY
RESTRICTED POSITION OF PACKAGE - LOADING PATTERNS 1 AND 2 ONLY APPLY

FIG. 6. Initial Orientation of Package in Container for Each of Six Loading Patterns Comprising SWAC Matrix

tions and the kaleidoscopic nature of this paper, the reader is referred to the complete monograph (1).

DETERMINATION OF STOWAGE SPACE LOSSES

Another disadvantage associated with containerization is the cubic losses in ships due to the wall thicknesses of containers and to the difficulty in stowing containers perfectly in different storage compartments (this latter loss is called broken stowage).

Scaled layouts of the stowage compartments and scaled templets of 15 different size containers were used to determine the stowage losses. Figure 8 illustrates this "hand fitting" methodology. In order to determine the upper limit of the ship losses, full containerization of the three hatches was assumed.

Figure 9 shows for different size containers the sum of the broken stowage and thickness losses by hatch as a percent of the available stowage space.

Before this analysis it was thought that the smaller the container, the smaller the ship space losses. However, Figure 9 disproves this thought. It shows, as in Figure 7, a periodic-like variation. It also shows the enormous space losses which were experienced with full containerization in hatches of this type which are typical of those in cargo ships. These high losses represent strong evidence for the need of ships specially designed to accommodate containers.

The author would like to suggest that a simulation technique on a digital computer similar to the one mentioned in the preceding section of this paper, could be used to investigate the fit of containers into ships.

TRUCK AND RAILROAD CAR SIZES

At the present time on the west coast there is little or no interchange of containers between trucks or railroad cars and ships. The labor-management agreements on the waterfront place severe restrictions on such interchange. If a shipping company owns the containers, then they can only be loaded and unloaded at the terminal by members of the union having jurisdiction over waterfront activities. Undoubtedly, this obstacle to progress will be overcome as the level of containerization increases.

An excellent compilation of the sizes of truck, railroad cars, and air cargo carriers is found in reference (2).

The author doubts whether there will ever be interchange of containers from aircraft to ships. The intrinsic characteristics of a commodity which render it desirable to transport by such rapid means as aircraft, would

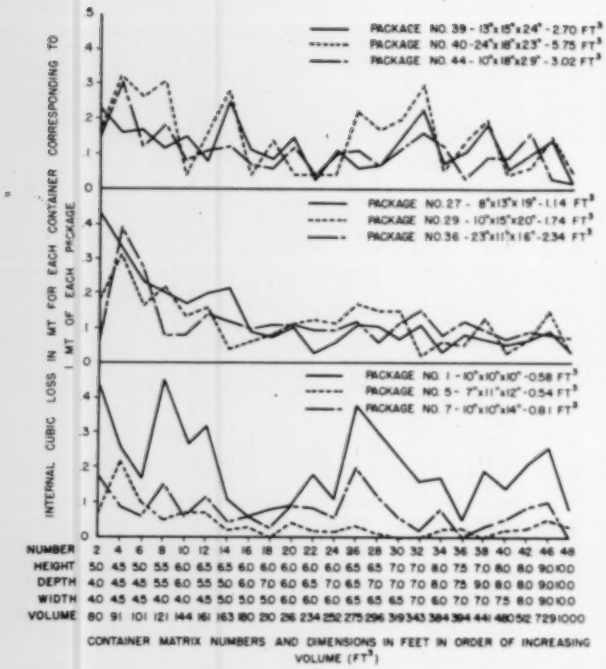


FIG. 7. Periodic-like Variation in the Internal Cubic Losses of Containers of Increasing Volume for Different Package Sizes

militate against transportation by such relatively slower means as ships. Hence, the influence of the sizes of air cargo carriers on shipping containers can be ignored.

DETERMINING THE OPTIMUM SIZES

The determination of the optimum size of a container would depend on the circumstances under which containers are to be used. In other words, the relative importance of each of the variables affecting the sizes of containers varies with circumstances. For example:

1. If, as at present, containers are not moved on trucks or railroad cars then the influence of these factors can be ignored.
2. If relatively few containers are to be loaded in a ship at a given time, then the influence of space losses due to ship fit can be ignored.

Assuming the long-run situation where containers will be moved on trucks and railroad cars and large numbers will be loaded on a ship at a given time, then the optimum size would be determined as follows:

1. Height of container—should be determined from ship fit considerations.
2. Width of container—should be determined from the influence of truck and railroad car sizes.
3. Depth of container—should be determined from a consideration of:
   (a) The density distributions of the physically containerizable commodities.
   (b) The fit of different size packages into different size containers.

DETERMINING THE ECONOMIC FEASIBILITY

The economic advantage or disadvantage of containerization over palletization varies from commodity to commodity. Figure 10 shows the dollar savings or losses per MT when each of these commodities is containerized instead of palletized. These savings and losses indices were determined for three different size containers. For each size container a determination was made for the situation where the maximum permissible weight limit on the ship's boom was 6000 lbs., and another determination for the case where the limit was assumed to be 12,000 lbs.

The intent here was to demonstrate the desirability of "beefing up" the booms to carry heavier lifts per load and thereby increase the productivity. The economic ad-

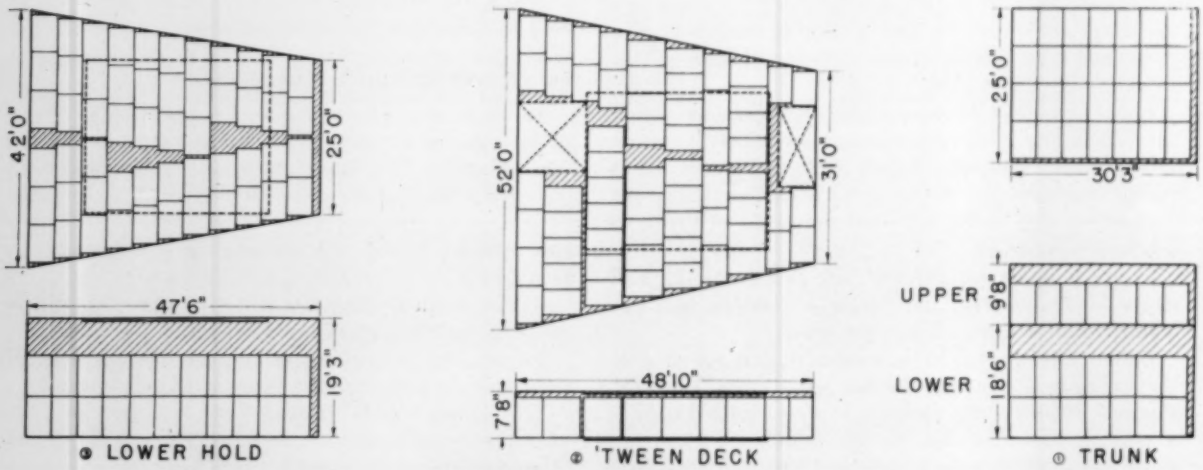


FIG. 8. Plan and Side View of No. 2 Hatch

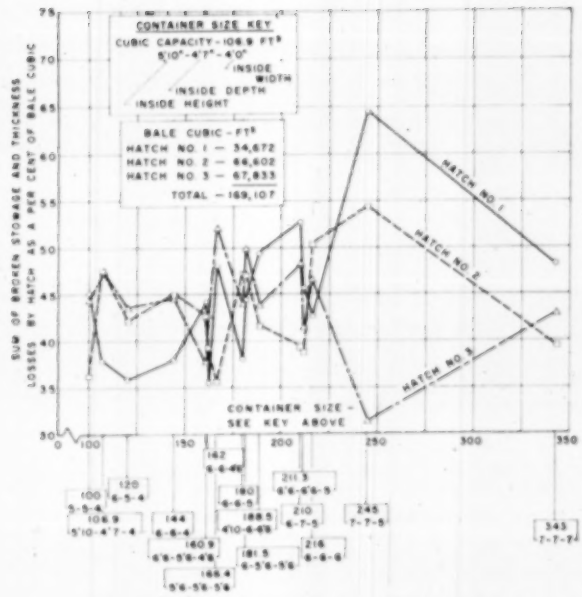

CONTAINER SIZE KEY
CUBIC CAPACITY - 106.9 FT³
8'10"-4'7"-4'0"
INSIDE WIDTH
INSIDE DEPTH
INSIDE HEIGHT
BALE CUBIC - FT³
HATCH NO. 1 — 54,672
HATCH NO. 2 — 66,602
HATCH NO. 3 — 47,833
TOTAL — 169,107
HATCH NO. 1
HATCH NO. 2
HATCH NO. 3
CONTAINER SIZE - SEE KEY ABOVE
SUM OF BROKEN STOWAGE AND THICKNESS LOSSES BY HATCH AS A PER CENT OF BALE CUBIC

Fig. 9. Hatch Cubic Losses in Percent for Different Container Sizes

vantages of heavier load lifts is more dramatically portrayed in Figure 11.

These savings and losses indices suggest the concept of a containerization priority index by commodity. If an operating man knew these indices for all containerizable commodities he would be able to rationally decide the order in which commodities should be assigned to containers.

The factors considered in this economic analysis were differences in loading rates or ship "turn-around" time, stowage space losses in ships due to containers, and costs of containers. Data on pilferage and damage losses were not available and therefore not included. Since these losses are considerable and since they are greatly reduced, if not eliminated, by containers, the estimated savings shown in Figure 11 for different levels of containerization are conservative.

The percent return on investment in containers shown on Figure 11 augurs well for containerization.

CONCLUSIONS

The methodology for determining the optimum sizes of shipping containers which was developed in this study for a specific trade route has general application. The kinds of data needed for such determinations have been indicated.

The economic analyses demonstrate that the potential dollar savings of containerization are staggering. This evidence strongly supports the statement made earlier in this paper that people in the shipping industry believe that containerization of general cargo represents the most promising innovation in the worldwide shipping industry. It is the author's opinion that the attractive investment opportunities represented by containers will result in the formation of companies who will engage in the rental business.

To fully exploit the benefits of containerization in the sort run, there should be standardization of sizes within the shipping industry. Ultimately, a national container system will probably evolve with size standardization agreed upon by all types of carriers. A U.S. Government sponsored group recommended such a system in 1936 (4). The intervention of World War II probably curtailed further activity along these lines. Groups like the International Cargo Handling Coordination Association (5) might provide the mechanism necessary for the development of national and international container systems. Such systems would probably serve as an impetus towards the much-needed standardization of package sizes.

Increased levels of containerization should simplify the setting of production standards and thereby make the cargo handling system more amenable to the application of wage incentive plans. Such plans should receive serious consideration in an industry which appears to rely

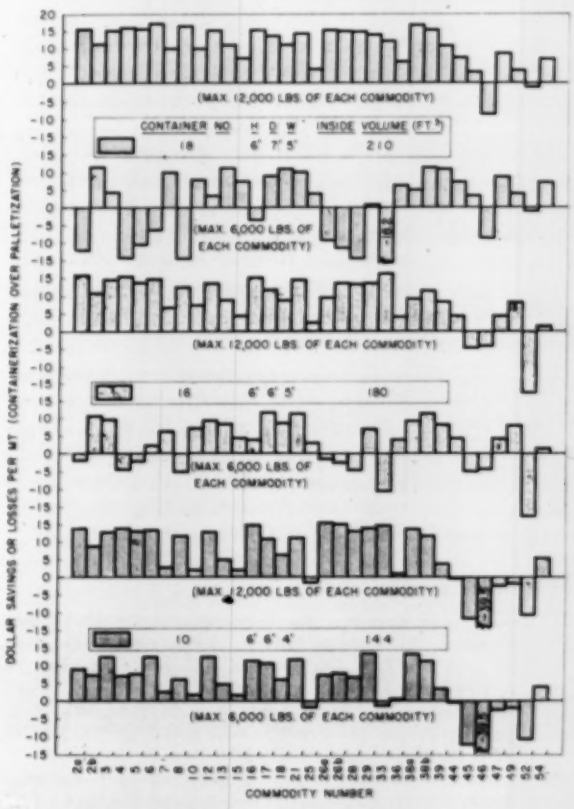

(MAX. 12,000 LBS. OF EACH COMMODITY)
CONTAINER NO. H D W INSIDE VOLUME (FT³)
18 6' 7' 5' 210
(MAX. 6,000 LBS. OF EACH COMMODITY)
(MAX. 12,000 LBS. OF EACH COMMODITY)
16 6' 6' 5' 180
(MAX. 6,000 LBS. OF EACH COMMODITY)
(MAX. 12,000 LBS. OF EACH COMMODITY)
10 6' 6' 4' 144
(MAX. 6,000 LBS. OF EACH COMMODITY)
DOLLAR SAVINGS OR LOSSES PER MT (CONTAINERIZATION OVER PALLETIZATION)
COMMODITY NUMBER

Fig. 10. Commodity Savings and Losses Indices for Determining Containerization Priorities

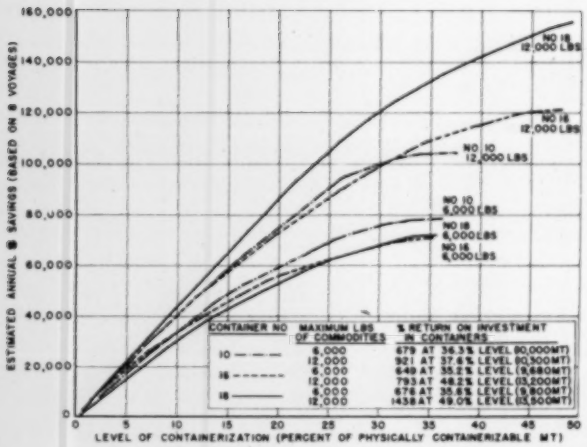


FIG. 11. Estimated Savings of Containerization over Palletization

heavily on the "art" and lightly on the "science" of management.

The author would recommend to shipping companies that they initially embark on a one-size container system, and with time grow into multiple-size systems. As with all innovations, there will be many problems which are difficult to predict. The design of distribution systems with appropriate controls will call for much ingenuity and experimentation. Experience with a one-size system would provide a framework which could be extended to handle multiple-size systems.

It is the author's opinion that management in the shipping industry is in dire need of the kind of "mental revolution" which has taken place in manufacturing industries under the impact of scientific management philosophies and techniques. If this research effort does nothing more than demonstrate the efficacy of analytical techniques in solving operational problems, it has highlighted a critical need. "Rule of thumb" methods must yield to scientific methods if increasing complexities are to be successfully coped with. Operating people, even if analytically equipped, don't have time for reflection because of the pressures of day to day problems. The author would like to recommend strongly that their efforts be augmented by properly trained Industrial Engineering or operations research staffs.

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Standards for Reading and Other Forms of Eye Activity

by GERALD B. BAILEY

J. D. Woods and Gordon Limited, Toronto, Canada

TRADITIONAL time study methods are designed primarily for use in setting standards for manual operations. The stop watch technician, either by direct observation of the job or by observation of a film record of it, can describe the method used in some detail. He can rate the work pace and, after adjusting the observed time by this rating factor, he can arrive at a standard time for the job.

This procedure, when properly applied, adequately takes into account both the manual part of the job and the eye activity that is used to direct the manual motions to their destination. However, the procedure is not always suitable for setting standards for independent eye activity such as that found in reading instructions or in examining material for defects. When independent eye activity is carried out, the observer is unable to tell directly either the nature of the eye motions used (method) or the work pace at which the eye motions are performed.

Time study observers have not been unaware of the importance of either method or pace in dealing with eye activity, but have usually had to be content to deal with them (and consequently all aspects of independent eye activity) somewhat indirectly. The usual procedure has been to assume that the method of using the eyes employed by the person under observation is correct, a practice that, by itself, could lead to questionable results. It has also been the convention to assume that the pace used to carry out the eye activity is the same as the pace used to carry out the associated hand and arm motions.

This indirect way of applying the rating factor to eye activity may also lead to questionable results. It breaks down completely where eye activity is carried out without movement of other body members.

As noted, time study engineers have long been aware that this indirect way of setting standards for eye activity had serious shortcomings. In setting standards for factory-type operations, however, the shortcomings of the method have not seriously affected the quality of their work. There are few factory-type jobs, usually limited to inspection jobs, where independent eye activity is a major part of the work. When a job involving eye activity comes up for study, more time studies are taken than would otherwise be necessary, or would be justified economically. Through sheer numbers of studies, the time study engineer has almost always been able to arrive at an acceptable answer.

Whether or not this method of setting standards for eye activity would have been followed indefinitely is speculative, for two events occurred to bring about a change in attitude. One event was the rapid growth of the clerical work force in industry and the need for clerical work standards. Routine clerical jobs would involve a degree of independent eye activity in almost every instance.

The other event was the development of research methods that were proving to be so valuable in investigating the characteristics of other forms of manual motions and in assigning times to these motions.

During the research program that was carried out to develop Basic Motion Timestudy, we came to believe that a more direct method could be established for evaluating eye activity than the traditional methods previously described. Detailed researches in this field were not carried out until the other BMT time data were developed and put to use. Then we returned to complete these researches and to test the procedures. This paper describes these procedures and the steps followed in their development.

THE PROBLEM OF METHOD AND PACE

A procedure for setting standards for independent eye activity must be capable of dealing with both the method of using the eyes and the pace at which the eye activity is carried out. The first step in the investigation, therefore, was to devise a test for which a rigid method specification could be established. This was not as difficult to do as might be imagined. We knew that to perform work the eyes jump from one point of focus to another, causing to perform their function at each new point of focus. In this sense, they move in a way that is directly comparable with the BMT definition of a basic motion—"movement of a body member that, being at rest, moves and again comes to rest." Also like arm motions, we knew (or at least strongly suspected at that time) that the eyes performed more than one type of basic motion. Later tests proved that this is so, although we have not tried to identify more than two types. These are referred to as Major and Minor eye motions. Of these, only the major type proved to be subject to clear-cut definition and thus to the assignment of a definite time value.

THE EYE TIME

A major eye motion was found to occur every time the eyes shift from one point on which they are focused, to another point, focusing accurately on the second point. Since this eye motion became the key to the resulting procedures, its definition needs to be clearly understood. The focusing act at the end of the major eye motion is precise rather than casual. It is not the glance one might make toward the telephone as he reaches for the receiver. The briefest look is all that is required here, often completed (and the eyes moved elsewhere) long before the hand reaches the receiver. Rather, it is the kind of focusing act one must use to read the first digit of a numeral. Also, the focusing act must be made to a single point. If there is more than one object on which the eyes must focus, they will very likely perform more than a single major eye motion. For instance, the time to shift the eyes to and read a 2 digit numeral is greater than the time for a 1 digit numeral. The 2 digit numeral takes a major eye motion and a minor eye motion. To be certain that it is made according to definition, therefore, this major eye motion must be directed to a single point. We gave to this eye motion the title Eye Time.

To assign a standard time value to an Eye Time, we set up a test comprising twenty separate positions to which the eyes could be directed. A single object was placed at each position. The positions were arranged so that the eyes could move progressively from position 1 to postion 20. Thus 20 Eye Times were needed to complete the test. We then had a number of experienced time study technicians perform the test in turn at slow, medium and fast pace to decide upon an appropriate standard time for it. From these results we selected a value of .008 minute per Eye Time. For ease in using this value with other BMT time data, the standard time for an Eye Time is normally referred to as 80 BMT units.

It should be noted that the standard refers to a work pace equivalent to walking at a rate of 3 miles per hour or dealing a deck of 52 playing cards into 4 bridge hands in .50 minute. It should also be noted that the value of 80 is a net standard time. Allowances for rest and personal requirements need to be added as required.

VARIATIONS IN METHOD OF USING THE EYES

The next step was to find out if the concept of eye pace could be transferred from the bench mark test of 20 Eye Times to some other action requiring independent eye activity. For this purpose a second test was devised. (Actually several such tests were devised and used. Since each test produced similar results, we need only refer to one of them.) This test was designed to develop a standard time for a paragraph made up of about 100 common English words arranged in several sentences. The subject of the first test, the 20 Eye Times, and the subject of the new test, which we shall refer to as paragraph number 1, were arranged side by side in front of the participant. He was asked to read the Eye Time test and, immediately after, to read paragraph number 1, using to the best of his ability the same reading pace in both cases. A standard time for paragraph number 1 was then determined by the Formula

$$\frac{\text{Eye Time value} \times \text{Number of Eye Times}}{\text{Actual time for reading Eye Time Test}} \times \text{Actual time for reading paragraph Number 1.}$$

Thus if a participant read the Eye Time test in .120 minute and paragraph number 1 in .250 minute, the standard time for the paragraph would be found by use of the above formula as follows:

$$\frac{.008 \times 20}{.120} \times .250 = .333 \text{ minute.}$$

Each participant went through a period of practice before any of his results were recorded. He was then asked to perform for the record, sometimes carrying out the test at a relatively slow pace, at other times at a relatively fast pace.

We asked each member of the first group participating in this test to perform it a minimum of twenty times. This group was made up almost entirely of experienced time study people who had been associated rather closely with the program. They knew how important it was to follow the method specifications most carefully. To the best of their ability they used the same method of reading throughout all trials.

The results obtained from members of this group were remarkably consistent. From a sequence of at least 20 consecutive trials by a participant it was not unusual to find that more than 75% of the calculated standard times for paragraph number 1 fell within a range of $\pm$ 7% to 8% of the average. Upwards of 60% fell within $\pm$ 5% of the average. Also, we found that the average time for the last five trials was almost invariably within 5% of the average time for the 20 trials. We decided, therefore, that on future tests, we would be able to accept a smaller number of trials. However, we would continue to ask each participant to go through a period of practice before his results were recorded.

During this examination we found one unexpected, or at least new development. While the results from each participant fell within a narrow range, the position of these results on a time scale was quite different, in many instances, from one participant to another.

The results showed a range of approximately 10% from the lowest to the highest time, but there the similarity ends. Participant A for example, produced an average standard time of approximately .22 minute. For participant D, an average standard time of approximately .33 minute was produced while the average for participants B and C fall at two different points between these extremes.

What was the cause of this wide range of times? Was it not possible for different people to transfer, in a uniform manner, the concept of pace for eye activity by the method under consideration? Or were the differences in average standard times a reflection of differences in reading method among a group of individuals?

In reviewing all results to that point we knew that many of the participants who now showed wide differences had taken part in the first test and had been in close agreement about the proper standard time for an Eye Time. We also knew that a uniform method of performing the first test had been virtually enforced on the participants. Each participant had to look in turn to 20 consecutive positions, at each of which his eyes had to focus on a single point. This clearly indicated that when method was held constant, essentially the same standard time would be obtained from each member of a group of participants. In other words, the results obtained from test 1 indicated that different people could in fact transfer the concept of pace for eye activity in a uniform manner.

Turning again to the results from the second test, we knew that each participant produced results from a series of consecutive trials that were in close agreement, with more than 60% of the results falling within a range of $\pm 5\%$ of the average. This clearly indicated that an individual could consistently transfer the concept of pace for eye activity.

This led us to a consideration of the final alternative —that differences were caused by differences in reading method or skill among a group of people. Those with relatively low standard times for the new paragraph would be able to read and understand what they read with fewer eye shifts and focuses than would those with relatively high standard times.

If it turned out that differences in reading method or skill were the cause of variations in standard times, it seemed likely that as more test results were added to those on hand, we would find a larger proportion of people would produce standard times for paragraph number 1 that were close to the average in the range. Some people, being required to use many eye shifts and focuses, would produce times that were somewhat higher than the average while others, using relatively few eye shifts and focuses, would produce times that were somewhat lower than the average. The average time would represent the proper standard time for the person with average reading skill. In short, is seemed likely we would find that reading skills were distributed in a reasonably normal manner.

We plotted all the results of test number 2 that had been obtained to this point on a frequency distribution chart and continued to add other results as more and more people participated in the tests.

Evidence of a normal distribution soon began to appear. A summary of more than 600 individual standard times obtained from more than 60 people is shown in Figure 1.

The eleven divisions into which the test results have been summarized represent time intervals of approximately 10%. Thus, if the different standard times obtained from the test represent differences in reading method or reading skill, this method of preparing the summary reflects reading skills above and below average on an equal basis. The number of occurrences that indicate a reading skill of 10% above average, for example, may be compared directly with the number of occurrences shown at 10% below average.

The average of the times shown in Figure 1 is almost exactly .28 minute. We started calculating the average time periodically when we had accumulated approximately 200 test results. It is interesting to note that the average time has never varied more than some $\pm 5\%$ from the value of .28 minute.

STANDARD TIME FOR THE AVERAGE PERSON

Although all the evidence that had been collected to this point indicated that the variations in standard times reflected variations in reading skill, there was as yet no conclusive evidence that this was so. This evidence could only come from additional tests. To this end, test number 3 was carried out. It made use of still another paragraph of English words. This new paragraph was somewhat longer than the paragraph used in test number 2 and both the words and sentence structure were considered to be somewhat more difficult. The test consisted of setting a standard time for paragraph number 2. We now used paragraph number 1 as the bench mark and assigned to it the standard time of .28 minute.

If the interpretations that we had placed on the results obtained to this point were correct, we would find that the same standard time, or nearly so, would be developed for paragraph number 2 regardless of who performed the test. The reading skill of the tester would, in effect, cancel out in the manner indicated below where:

$A1$ = actual time for paragraph number 1.

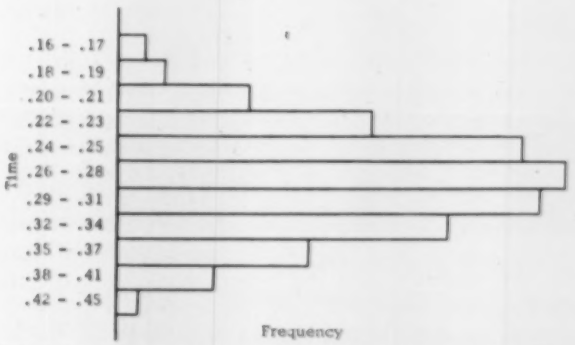

Fig. 1. Net Standard Times in .01 Minute for Paragraph Number 1 Shown in Intervals of Approximately 10%.

Participant No.	Paragraph Number 1		Paragraph Number 2		Percentage Deviation From Average
	Actual Time	Personal Standard Time	Actual Time	Standard Time	
1	.280	.330	.488	.488	+1.5%
2	.358	.300	.621	.486	+1.0%
3	.208	.260	.354	.476	−1.0%
4	.264	.220	.446	.474	−1.5%
				Total for 4 tests—1.924	

Average standard time for paragraph number 2 = 1.924 ÷ 4 or .481

Note: Times are shown in .001 minute.

FIG. 2. Summary of Results Obtained from 4 People with Widely Different Reading Skills when Steps Were Taken to Neutralize Differences in Reading Skills.

$A2$ = actual time for paragraph number 2.
F = factor representing the percentage by which the tester's ability deviates from average.
.28 = standard time assigned to paragraph number 1.

Standard time for paragraph number 2

$$= \frac{.28}{A1 \times F} \times A2 \times F$$

For this test we asked for assistance from people who had also taken part in test number 2. We deliberately chose people who, based on the results of test number 2, exhibited wide differences in reading skill. Some of these people had developed a "personal" standard that was considerably higher than the average of .28 minute. Others had a personal standard that was considerably lower than the average while still others had a personal standard that was at or close to the average of .28 minute. The results we obtained from 4 people, representing a wide range of reading skills, are summarized in Figure 2.

The standard time for paragraph number 2 was calculated by the formula

$$\frac{.28}{A1 \times F} \times A2 \times F,$$

which was described earlier. The deviation was calculated as the difference between the individual standard time for paragraph number 2 and the average of the 4 results (.481 minute), expressed as a percentage of .481 minute.

The personal standard times shown for paragraph number 1 were obtained in test number 2.

Other tests carried out in the same manner and involving paragraphs taken from other material have produced similar results.

These standard times for paragraph number 2 show a remarkably high level of consistency, no doubt being higher than may reasonably be expected. However, more than 75% of the results obtained so far have fallen within a range of ± 5% of the average standard time for the paragraph and the highest deviation has been only approximately 7% from the average. From such results, the following conclusions were made.

1. The variations that were obtained in the standard times for paragraph number 1 were almost if not entirely caused by variations in the reading ability of the individuals participating in the tests.
2. By summarizing the results obtained from a large number of people, a normal appearing distribution of times was obtained. The average of these times represents the proper standard time for the person with average reading ability.
3. The concept of pace for eye activity can be transferred with the same degree of consistency that can be obtained in stop watch study of unrestricted manual work.
4. When inherent differences in reading skill are not a factor (i.e. the exact method of using the eyes may be specified), pace may be evaluated by the use of a bench mark consisting of a series of Eye Times in the manner described for test number 1.
5. When inherent differences in reading skill become a factor, the evaluation of pace should make use of a bench mark that will neutralize the effects of these differences in the manner described for test number 3

To emphasize these conclusions, we prepared a summary to show the standard times that would have been developed for paragraph number 2 if the calculations had been based on the personal standard for each of the four participants listed in Figure 2. This summary is shown in Figure 3.

There are wide differences in the standard times when this method is used. The deviations from the average standard time are many times greater than the deviations obtained by the procedure used in Figure 2, which are shown in the right hand column of Figure 3 for comparison.

USES OF THE PROCEDURE

Time standards for eye activity may be established by the procedures outlined for both factory-type and clerical-type work. Except for inspection-type operations, there are few instances in the factory where independent eye activity forms an important part of the work. However, the procedure outlined has direct application in these instances. The major application is in clerical-type operations where a considerable amount of reading must be carried out. The nature of the reading may be quite different from one setting to another but its purpose will be the same. The eyes, focused on one point, read instructions that describe the action that is to be carried out at some other point. The information read may be the address on a letter, telling the mail sorter where the letter should be placed in the sorting case; it may be information that is to be entered into a

Participant No.	Paragraph Number 1		Paragraph Number 2		Percentage Deviation From Average	
	Actual Time	Personal Standard Time	Actual Time	Standard Time	This Summary	Summary in Figure 2
1	.280	.330	.488	.575	+20.5%	+1.5%
2	.358	.300	.621	.520	+ 9.0%	+1.0%
3	.208	.260	.354	.442	− 7.3%	−1.0%
4	.264	.220	.446	.372	−22.0%	−1.5%

Total for 4 tests—1.909

Average standard time for paragraph number 2 = 1.909 ÷ 4 or .477

Note: Times are shown in .001 minute.

FIG. 3. Summary of Results Obtained from 4 People with Widely Different Reading Skills when No Steps Were Taken to Neutralize Difference in Reading Skills.

ledger or other record; it may be information to be typed or otherwise recorded by key-operated machines. Whatever its nature, the testing procedure outlined above may be used to determine the standard time for performing the work.

In this connection we should direct attention to an important quality of the procedure that has already been mentioned but should now be emphasized. The standard time that is developed by the procedure may be described as the time to read (or otherwise use the eyes) and understand what has been read. In reading, this is a matter of looking at as many syllables of each word as is necessary in order to understand the meaning of the word and its relationship to the words that have preceded it. At times this may involve shifting the eyes back to reread syllables or entire words. At other times the meaning may be so clear that syllables or even words may be skipped. In examining material for defects, this would be a matter of locating a defect and deciding whether the defect, according to established standards of quality, would cause the material to be graded lower or even rejected.

APPLYING THE PROCEDURE

Although our main purpose is to describe the procedure for evaluating the work pace of independent eye activities, some comments concerning the method of applying the procedure should be made. To start with, we should point out that the term independent eye activity is, to a certain extent, a misnomer. Actually, eye activity is seldom completely divorced from manual action. The separate actions of the eyes and of the fingers, hands and arms may be carried out at the same time or partly at the same time and partly in sequence. Sometimes the work performed by the eyes will take longer than the work performed by the hands. At other times the opposite will be the case. Rarely will it be possible to tell by observation alone which action controls the work. Therefore the steps to be followed in setting standards for work that includes eye activity should provide a basis for evaluating separately the work performed by the eyes and by the fingers, hands and arms.

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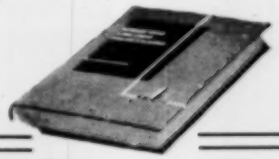

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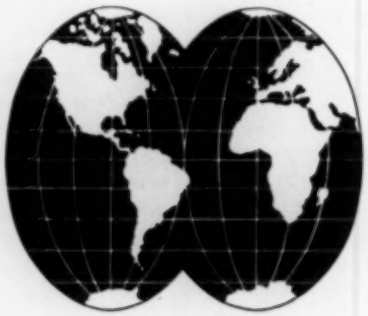

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President's Message

GEORGE H. GUSTAT

President, American Institute of Industrial Engineers, Inc.

1958-59

The Attraction of Industrial Engineering

A GLANCE through the summaries of qualifications of candidates for national office in the American Institute of Industrial Engineers for the past two years reveals an interesting fact: only 18% of these candidates have an undergraduate degree in Industrial Engineering, the remainder holding degrees in other branches of engineering and in mathematics, business and other areas. Is this startling? Is it something to be concerned about? Not really. What it probably means is that we are practicing the profession of engineering and that branches, such as electrical, civil, industrial, etc., are of importance only as they are parts of the entire profession.

Before pursuing this thought, perhaps it would be helpful to look at some of the reasons for the varied educational backgrounds in our field. Why do graduates of other engineering branches enter the practice of Industrial Engineering? Much of the reason comes from personal interest and motivation. In most jobs, by the very nature of Industrial Engineering, we are dealing not only with the physical sciences, but the social sciences as well. This, of course, we have recognized in our definition of Industrial Engineering as it appears in the **Journal**. Because this is the case, many engineers find that their interests and abilities fit this area of machines and men better than they fit the area of physical science applications alone. The Industrial Engineer has the need to use the social sciences when the personnel factor is introduced into the engineering problem. He is forced to use his basic engineering approach in an even broader, and in some respects more challenging, sphere of activity—the not-so-well-defined area of the human being; how he works; his relation to the machine and the organization. If the engineer's interest so dictates he has an opportunity to get away from classical design problems and into the problems of effective use of men, materials and machines.

For many engineers the practice of Industrial Engineering provides the first step into operating problems and an opportunity to go further into management responsibilities. This variation in scope of work is much broader than the more classical fields of engineering design, installation and maintenance. The transition from method and measurement to production operations, to general management, is more logical than from the starting point of engineering design. Therefore, the opportunity for each engineer to develop to his own level of ability and interest is more readily available than in the other engineering practices. This has been materially aided traditionally by the encouragement of Industrial Engineering managers whereas it has more commonly been discouraged by Engineering managers in other fields. The attitude of the latter group of men has evolved around the thought of keeping engineers on engineering work and allowing non-technically trained men to ad-

minister and manage the business.

These are some of the factors working on the individual which are influential in his choosing work somewhat different from his formal educational background. In addition to this motivational drive, there are some other conditions which are important to the individual because they make the choice of Industrial Engineering practice feasible. It has been found that any individual with the proper aptitude and interest and who has a basic engineering training can translate the engineering approach of his own branch into Industrial Engineering practice. The teaching of the fundamental tools of Industrial Engineering and methods of analysis to a man with a basic engineering background in any branch has been done many times in the past. The future may not provide this same ease of transition, however. As the scope of Industrial Engineering investigation continues to broaden, as it has been doing quite rapidly, the demands also increase rapidly. These demands center around techniques for solution of problems which require substantial training and experience not easily absorbed in a short time. The further we progress in this direction, the more difficult will such transition be.

It has been a rare occasion when a man with an Industrial Engineering educational background has taken up practice in other branches of engineering. Probably those originally choosing training in Industrial Engineering rarely became interested in other practice, hence do not as frequently make the transition to some other branch. It is not intended to infer that an Industrial Engineering education is undesirable, but rather to partially explain why many engineers with other backgrounds seem to gravitate into Industrial Engineering practice. There is another element of significant importance enhancing this condition. The supply of well trained Industrial Engineers has fallen far short of the need in recent years, thus encouraging the attraction of good men into Industrial Engineering practice by providing many job opportunities with good advancement potential.

Thus far, I have been examining the attraction of Industrial Engineering practice from the viewpoint of the individual engineer. A look at the same question from the viewpoint of an employer is also interesting. One might wonder why any employer would hire an Electrical Engineer to do Industrial Engineering when he might have hired an Industrial Engineer in the first place. What might the reasons be that would cause an employer to hire such a man? Many companies have found that Industrial Engineering work provides a solid foundation in preparation for other line and staff assignments. The broad aspects of products, processes, manpower and business operation that can be absorbed by an engineer in several years of Industrial Engineering practice appear to be much greater than that gained by the neophyte engineer who is assigned to modest projects (or the drawing board) in other branches of engineering. Two years of establishing methods and measurements in several operating departments are very likely to give a young graduate a much broader appreciation of company policies, competitive practices, industrial relations, product needs, costs and cost systems, etc., than any similar kind of experience could provide in a more straightforward engineering branch practice.

At the same time, mechanical, chemical, civil or electrical backgrounds may be very useful in understanding and contributing to the particular operating area to which the man is assigned. For example, in a company which is making electric motors and motorized subassemblies for automobiles, an Industrial Engineer with either an electrical or mechanical engineering education would be very useful in at least two ways. First, this fits a common pattern with the designers, producers, salesmen and consumers as far as language and problem appreciation are concerned, as well as practical compromises. Second, it has frequently been found that some knowledge of the theory and practice underlying a particular product or process will allow the Industrial Engineer to make contributions for improvement that he otherwise would not have recognized. In the case mentioned the electrical or mechanical engineering background might prove useful in just these ways. Another point, in terms of the later assignment or transfer of the man to other work is almost obvious. While the general broadening and company education afforded by Industrial Engineering practice are desirable in preparing a new engineer for other work in the organization later, an extensive familiarity with, and knowledge of, some other branch of engineering, such as chemical, electrical or mechanical might be a virtual necessity. Further, from the viewpoint of the employer a mixture of backgrounds in an Industrial Engineering activity takes on many of the desirable aspects of the highly advertised operations research team approach involving a mixture of disciplines.

The foregoing outlines the reasons, both from the standpoint of the individual and from the standpoint of the employer, why education backgrounds other than Industrial Engineering may prove to be a very desirable asset to an Industrial Engineering activity. From the viewpoint of the Industrial Engineering practice should this mean that Industrial Engineering is not a full-fledged citizen of the engineering field? By no means! Not only are the technical requirements the same as for any other engineering field insofar as basic engineering materials and methods are concerned, but in addition there is still a further requirement. This additional requirement, uniquely important to the Industrial Engineer, is that the individual be adaptable to working with *people*, at all levels of organization, from the operator to the Chairman of the Board of Directors, if necessary. Not only must he be able to do this; he must enjoy it, be lucid and convincing and compatible with all the view-

points and aspects of a business organization. In any one of the fields of engineering technical brilliance might suffice to allow a man to stand out as one of the few for whom his associates are willing to tolerate idiosyncrasies for the sake of technical brilliance. In Industrial Engineering the man who will stand out as a brilliant Industrial Engineer will be the man who not only stands out because of technical brilliance, but also because of the well rounded and well balanced total man and total Industrial Engineer. This means, then, that he must have some technical brilliance, that he must have some social brilliance (in the sense of ability to deal with people), consideration for people and a welding of the two, the social and the physical, into an acceptable pattern for operation. Perhaps the difficulty of clearly delineating these things and teaching the student how to practice them is one reason some people find desirability in educational preparation in one of the more classical branches of engineering and a later selection of Industrial Engineering practices where they learn these other associated requirements through on-the-job training. More and more men are attempting to accomplish this through graduate degree work in Industrial Engineering or Business Administration. When coupled with an undergraduate degree in Science or other branches of engineering, an attractive preparation for Industrial Engineering practice often results.

To summarize, then, Industrial Engineering appears to attract engineers in both schools and industry from other branches because of personal interest, because it is a feasible transition, and because it offers some very tangible value; not only to the Industrial Engineering activity, but to management in providing a broader training for various line and staff positions. Industrial Engineering also offers a place to the engineer who is operation or management centered, rather than engineering design centered.

Whether we individually agree or disagree with the preceding thoughts, a hard fact remains—for many reasons, the majority of engineers practicing Industrial Engineering today have taken their formal educational training in some other branch of engineering and subsequently transferred their interest and activity to the practice of Industrial Engineering. As Industrial Engineering teaching and curriculum produce an adequate number of graduates meeting the high standards for engineering education set by ECPD, this is very likely to change in magnitude.

I believe that this leads us to the point that *we*, better than any other branch of engineering, should recognize and militantly promote engineering as a profession and Industrial Engineering only as a particular practice in that profession. The sooner engineers as a whole accept this and join forces in every way, the sooner we will be able to devote our energies to progress as a profession and not to defending our own sphere of activity.

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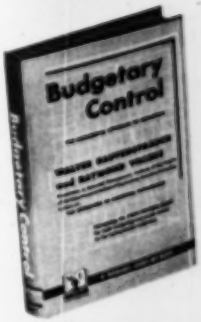

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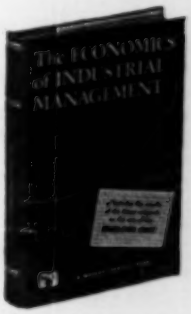

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Reader Comments

While reading Mr. Blair's article on "A Fresh Look at the Principles of Motion Economy," it brought to mind a very interesting idea that Mr. Lescault and I devised in our instruction class for Industrial Engineers here at Remington Rand.

When an Industrial Engineer is making an Act Breakdown for a Left and Right hand chart in his time study work, we suggested that if he would think of the American Institute of Industrial Engineers or AIIE, he could remember to do the following things:

A. Analyze.
I. Investigate.
I. Improve.
E. Eliminate.

This information may be of interest to other Industrial Engineers, so you may pass along the idea in anyway you may so desire.—*R. Weinberg, Remington Rand, Elmira, New York.*

DEMAND FOR INDUSTRIAL ENGINEERS

Hoff, Canny, Bowen & Associates, New York Executive Search Specialists, in a survey just completed of the scientific-technical executive personnel needs of over 1,000 leading U.S. industrial firms, report that Industrial Engineers are in great demand now. In five years, the demand for mechanical and Industrial Engineers leaps to first place. Major firms are already actively seeking executive personnel in these categories.

Hoff, Canny, Bowen point out that these major firms are offering not only salary inducements, but generous fringe benefits, profit sharing, bonuses, stock options, opportunities for advancement, pleasant working conditions, and freedom to make decisions.

This trend will grow because many experts anticipate that the next big boom will occur in five years. And for an expanding economy—for greater plants and equipment—the mechanical and Industrial Engineers are the keystones.

Even the recession has brought no slackening of demand for top industrial and mechanical engineers. Many of the new plants have been working at top capacity during the boom. These plants and their managements were strained and there was no opportunity for the management or the equipment to rest, or for the bugs which had developed to be worked out. Now management is taking a breather to improve both facilities and manpower.

The companies indicate that they want Industrial Engineers who also know something about a particular industry. Companies want Industrial Engineers to know enough about their particular business, so that the Industrial Engineer can plan the entire plant for future expansion. If it is a missiles plant, the Industrial Engineer must know enough about chemical engineering and physics to see where revolutionary changes now in the speculative stage may cause radical alterations of the entire plant and be prepared to allow for such changes in his planning now. If it is a chemical business, the Industrial Engineer must have some idea about theoretical changes in chemical fuels, plastics, etc., which may require drastic innovations—and allow space for these in his planning now. So the Industrial Engineer of today must be much more than the old straight Industrial Engineers of yesterday who concentrated on routine plant lay-outs, time-and-motion studies, and efficiency techniques.

There is also a great demand for chemists, chemical engineers, physicists, electrical engineers, electronics engineers, electromechanical engineers, and organization planning specialists for the next five years.

Those commanding the highest salaries will be mechanical engineers, Industrial Engineers, chemists, chemical engineers, electrical engineers, electronics engineers.

Some economists feel that this scientific-technical executive personnel demand is an additional and accurate index of economic conditions in various industries. The demand for industrial and mechanical engineers proves that industry can look forward to a prosperous and active economic climate in the years ahead and that young men planning their schooling now should be aware of future opportunities in this field.—*(Dr.) Dorothy Gregg, Consulting Economist, Hoff, Canny, Bowen & Associates, Inc.*

THE BASIC LIMITATIONS OF OPERATIONS RESEARCH IN INDUSTRY, by George S. Odiorne, *Journal of Industrial Engineering,* September-October, 1957.

It is an old truism that we never appear to others as we appear to ourselves. Further, it is not at all unlikely that *some* (but not all) others can know better what we are up to than we do ourselves. In Mr. Odiorne's discussion of Operations Research I find a peculiar mixture of understanding and revealing insight on the one hand, and verbal juggling and misrepresentation on the other.

I think his observation that OR is not a way of managing but is "a tool of a specialist who applies his technical knowledge under managerial direction" is sound and agreed to by almost all practitioners. He implies that practitioners would not agree. This is nonsense. He writes, "A considerable number [of OR scientists] have enlarged its ambit of operations through methods that are more reminiscent of the book 'How to Succeed in Business without Actually Trying.'" No references are provided. I would like to see evidence of this "considerable number."

In his discussion of the assumptions underlying the practice of OR his main point is that "the predominant philosophy of science held by most OR men is one which is sometimes identified as 'positivism.'" Now either Mr. Odiorne does not understand positivism or he does not understand OR. If there is any underlying and unifying philosophy of science in OR it is "pragmatism," or, more precisely, that type of pragmatism called "experimentalism" (4) (5). His description of the hierarchical approach to problems by OR men is not accurate. The various efforts to explicitly formulate the OR approach (6) reveal to even the casual reader that the metaphysical perambulations attributed to OR men by Mr. Odiorne are a figment of his imagination.

Let me be specific and document Mr. Odiorne's inability to do at least a certain type of elementary research and to read accurately. He refers to certain of my conclusions as those of a logical positivist. I cite the record in which, together with C. West Churchman in our earlier careers in the philosophy of science, we attacked logical positivism as an inadequate philosophy (1) (3) (4) (5) (6) (7).

He also writes that one of my articles (2), suggests "that management will become 'automatic' in the future through the application of mathematical decision making, abetted by the computer. . . . What is implied is not that present managers have to change, but that they must abdicate." Let me just quote some relevant passages from the article to which Mr. Odiorne refers and demonstrate either his lack of understanding or conscience.

"In my opinion, operations research is the bridge over which the present is passing on its way to what I call 'automatic man-

agement.' This term is likely to antagonize many but I feel it may call for attention from some who would not otherwise pause to think about the extension of automation into management's domain. . . .

"Some may choose to discredit this forecast as visionary or may begin to fear that management may soon be confronted by technological unemployment if this forecast is correct. The fear is unfounded even if my forecast is correct. . . .

"I would rather state positively what I believe will be the effect of automatic management on management.

"1. Automatic managers will themselves have to be controlled. Models and instructions and problems will have to be placed in them. Human managers will do this. But, you may say, this requires a degree of technical knowledge most human managers do not have. True, they may not have it now but they *will* have it. Today's managers have considerably more technical knowledge than the manager who controlled industry before the first industrial revolution. Today's management to a large extent is technically trained to a degree undreamed of by management of previous generations. The increase in knowledge required by tomorrow is no greater in quantity but is different in content from that required to move from yesterday to today. And like its preceding evolution it will not happen in one generation. Today's management will not have to learn all the new things, but its responsibility lies in initiating an expanding training of management that will continue in the generations between the *now* and the *then*.

"2. Most complex management problems will not be capable of complete automation. Electronic brains will handle only those factors which can be quantified. In many, if not most cases management will still have to add its experience and judgment before a complete decision is reached. But human managers will be relieved of the routine aspects of decision-making such as examining and analyzing large quantities of data and and minimizing the sum of identifiable costs.

"Furthermore, at any stage in the automation of management there will be certain decisions not yet susceptible to automation. These will be the more complex decisions involving the many intangibles of the day, including ethical, moral, political, and esthetic problems. Human managers will be freed by the automatic managers to give these problems the time they require, which time, were it not for the automatic managers, they would not be free to give, and, in fact, cannot give today. We have not and probably will not ever mechanize every manual operation. A seemingly infinite number will always remain. Similarly, we will never reduce all problems to a form where the automatic manager can take over. The solution of any problem always forces man to become conscious of another he had hitherto ignored. This is the essence of progress—to move from lower order to higher order problems, to become increasingly self conscious and self-evaluative. In brief, automatic management will create at least as many problems for human managers as it will solve. These new problems, yet to be created and yet to rise to consciousness, will help tomorrow's human manager to be more effective than the manager of today."

In my opinion, what Mr. Odiorne has to say about what OR can and can't accomplish is quite accurate. OR is only a way of using scientific methods, techniques, and tools to assist the manager in making better decisions. It is not a substitute for management but it can relegate to the routine certain types of repetitive management decisions, and it can and has been used to solve complex non-repetitive problems as well. There is a considerable tendency to oversell OR but most of this has come from associations and societies which have tried to exploit the popularity of OR by filling conferences, workshops, and seminars, which have large registration fees associated with them. No such meeting has ever been conducted by any society of professional OR men.

What Mr. Odiorne has to say about how OR is done, its underlying philosophy, logic, and method is fiction. No professional OR man takes the physical analogues to which Mr. Odiorne refers as seriously as he does. They are heuristic *devices*, not principles or solutions to problems. What he has to say about probability evades my comprehension: "Before OR can be adopted as a model of decision making in many areas of management it must more logically define the degree to which their rational decisions or laws of management bring order into the jungle of intuition, emotion, and reasoning by experience hunch." This isn't a matter of definition, it is a matter of demonstration. If the past demonstrations by OR had been less convincing it would not be necessary for Mr. Odiorne to expend so much energy cautioning others not to become overenthusiastic.

"Over-anything" including "overselling" is a "bad thing" but so is "under-anything" including *under*estimating and and mis-*under*standing.

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—Russell L. Ackoff, Director, Operations Research Group, Case Institute of Technology

AUTHOR'S COMMENTS

Mr. Ackoff, a redoubtable and respected figure in OR reinforces the need which my original article sought to point out. I sense that he is pleading personally "not guilty"—and rightly so—to the charges I make that a lunatic fringe exists in OR circles that is doing serious damage to the art. Unless the cultists and opportunists can be drummed from the clan by the more rational practitioners, the very recklessness and irresponsibility which they show will discredit even the best.

Mr. Ackoff imputes this irresponsibility only to "societies and associations" to which list he might have added some consultants, some corporate staff people and perhaps a college professor here and there.

I must confess that I can't give any statistics about the quantitative scope of this cultism in OR, any more than I could of a more general lunacy in the whole population. I can only judge from the OR men I've met and heard, and seen in action, which ones I considered serious and responsible professionals, and which ones—to put it delicately—are less adequate.

Mr. Ackoff can't escape wholly unscathed, however. I sense from his article and the portions quoted above that he stands with reluctant feet where the scientists and humanists meet, and can only hope he maintains his balance. For example, he tipped over a bit when he was in one of his provocative moods and coined the phrase, "automatic management."

Not everyone in OR is as rational as Mr. Ackoff, nor is every OR team blessed with a philosopher as is the Case Institute in the person of C. West Churchman. I would suggest that perhaps

more people such as Mr. Ackoff ask themselves, "what are we going to *do* to keep professional standards high in OR?", and perhaps a few more articles identifying the bugs in OR would be appropriate.—*George S. Odiorne, Director, Intra-Company Management Program, American Management Association.*

AN APPLICATION OF LINEAR PROGRAMMING TO THE ASSIGNMENT OF MATERIALS HANDLING EQUIPMENT, by Virgil Erickson and Paul H. Randolph, *Journal of Industrial Engineering,* November-December, 1957.

In its present form the work reported by Virgil Erickson and Paul H. Randolph under the title "An Application of Linear Programming to the Assignment of Materials Handling Equipment" is apt to give a reader several misconceptions of the value and limitations of Linear Programming in this particular type of application.

In this paper, three materials handling resources—conveyor, automatic palletizing, and manual palletizing—are allocated among twelve product lines. Two of these resources have a linear relationship between cost (man hours) and pounds of materials handled. The third resource (automatic palletizing) does not exhibit this linear relationship. As stated by the authors, each item of automatic palletizing equipment can handle the output of one and only one production line in a day independent of the amount produced by that line.

The authors chose to approximate the characteristics of the automatic palletizing equipment with a linear function so that linear programming could be applied. As the authors pointed out, the resulting linear programming solution is not the optimal one. Unfortunately, the authors do not make it clear that this does not stem from any inherent weakness in the linear programming technique but from the approximation of a nonlinear function by a linear function. As a matter of fact, when the limitations of automatic palletizing are taken into account correctly, there is another solution to the assignment problem that is lower in cost than either the linear programming solution or the modified solution given by the authors. This lower cost solution would in the terminology of the authors of this article involve assigning product line 8 of 117,000 pounds to automatic palletizing and product line 9B producing only 33,000 pounds to manual palletizing. The saving, again in the terminology of the authors, would be of the order of 3.7 man hours. The major conclusion that can be drawn from the foregoing is that considerable exercise of judgment is required when an attempt is made to apply linear programming to problems in which one of the major relationships is not linear.

There is a second and somewhat less serious criticism that can be made of this article. The actual problem of assignment involving only three types of equipment is sufficiently simple that it can be solved by inspection in much less time than it can be solved by linear programming. It takes approximately ten minutes to solve this problem by inspection. I agree that it is useful to publish articles on the application of linear programming when the example chosen is simple enough that it can be solved by inspection. This is a standard and valid pedagogical technique for illustrating the application of a complicated method of analysis. However, the authors of such papers should clearly state that the problem has been simplified to demonstrate the application of a method of analysis. Otherwise, the reader is apt to draw the conclusion that all applications of the method of analysis (linear programming in this case) are easier to solve by inspection than by the use of a more sophisticated technique.—*David E. Debeau, Department of Economics, Battelle Memorial Institute.*

THE ASSIGNMENT OF WORKERS IN SERVICING AUTOMATIC MACHINES, by Docent Conny Palm, *Journal of Industrial Engineering,* January-February, 1958.

Your article "The Assignment of Workers in Servicing Automatic Machines" translated by Lovgren was most interesting. However, in going over some of the mathematical derivations I noted some printer's errors which may be of interest to others.

Since these equations lead to Eq. 52. (which is correct), the errors only effect the steps in the derivation. I pass this information on to you for what it may be worth should any questions arise.

Eq. 48, should be:

$$Q_0 = Q_m + \frac{b}{m} Q_b + \frac{d}{m} Q_d + \frac{1}{mn} Q_e$$

Eq. 50. should be:

$$Q_0 = Q_m + kQ_b + Q_e \frac{Vd + \frac{1}{n}}{m}$$

Eq. 51. should be:

$$\frac{Vd + \frac{1}{n}}{m}$$

Eq. 51a. should be:

$$Vd + \frac{1}{n}$$

—*Peter K. Studner, Glenbrook, Connecticut.*

On page 35, column 1, the sixth line from the bottom should read $k = 0.1$ instead of $k = 1$.

There is a linotyping error in the heading in Table 2, page 38. $V_e + 1$ should have been set as V_{e+1}.—*Sidney I. Neuwirth, Manager, Operations Research, Johnson & Johnson, New Brunswick, New Jersey.*

WALTER RAUTENSTRAUCH'S PIONEERING WORK—A 50TH ANNIVERSARY, by Raymond Villers, *Journal of Industrial Engineering,* January-February, 1958.

In Dr. Raymond Villers' recent article, the following phrases appear on page eight: ". . . To serve this purpose, he offered as a tool of management *his* now famous *break-even chart.* . . . Actually, ***Rautenstrauch's break-even chart*** . . ." (italics supplied). These statements suggest that the break-even chart was the invention or creation of Walter Rautenstrauch.

As a popularizer of the terminology of break-even analysis and as a popularizer of one of the two main versions of the break-even chart, Walter Rautenstrauch stands without peer. But the credit for the origination and creation of the break-even chart belongs, if it belongs to anyone, to Henry Hess.

Henry Hess, in 1897 at the time Walter Rautenstrauch was a 17-year-old high school student in Missouri, published a paper that clearly makes the distinction between fixed and variable costs with respect to the volume of operation, a distinction basic to the break-even chart (1). And in 1903 just after Walter Rautenstrauch completed a master's thesis on the design and construction of ships, Mr. Hess published a *copyrighted* break-even chart very similar to the ones Walter Rautenstrauch later popularized (2) (5). Walter Rautenstrauch in his 1903 thesis gives no basis for even assuming he was aware of the distinction between fixed and variable costs with respect to volume, a distinction that is fundamental to the design and construction of break-even charts. In fact, even as late as 1918, Walter Rautenstrauch made little if any published use of this fundamental distinction (4). And this is odd, because both Henry Hess and Walter Rautenstrauch were members of the Columbia University Mechanical Engineering faculty in 1908-1909 (8).

In any event both Walter Rautenstrauch and Henry Hess have

claimed originating the break-even chart and manifestly they both cannot be right (2) (5). In fact, the first published break-even chart that Walter Rautenstrauch presents was in 1922 (the year Henry Hess died) yet others prior to that time mentioned break-even charts of both schools of thought (3) (6) (7).

For these reasons, I am surprised to see Dr. Raymond Villers suggest that Walter Rautenstrauch's pioneering work included the break-even chart. In fact, I am doubly surprised because this matter has been publicly called to Dr. Villers' attention before, and he has publicly acknowledged his awareness of the facts.

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(3) Knoeppel, C. E., *Graphic Production Control*, The Engineering Magazine Co., New York, 1920, p. 378f.

(4) Rautenstrauch, Walter, "Manufacturing in Relation to Banking, Research, and Management," *Journal of the Engineers Club of Philadelphia*, V. 35, No. 159, February 1918, p. 81ff.

(5) Rautenstrauch, Walter, and Villers, Raymond, *The Economics of Industrial Management*, Funk and Wagnalls Company, New York, 1949, p. 80.

(6) Reuter, F. J., "The Break-Even Point Chart a Management Tool," *Manufacturing Industries*, V. 11, No. 4, April 1926, p. 290.

(7) Villers, Raymond, "The Development of the Break-Even Chart: A Bibliographical Note," *Journal of Business*, V. 28, No. 2, April 1955, p. 148f.

(8) Unpublished correspondence between Columbia University and Ned Chapin.

—*Ned Chapin, Menlo Park, California.*

AUTHOR'S COMMENTS

Thank you for giving me the opportunity of answering the letter you received from Mr. Chapin.

To begin, I am surprised by the last paragraph of his letter, which implies that I once acknowledged anything contrary to the views expressed in my recent article. Actually, Mr. Chapin is referring to my letter to the editor of the *Journal of Business of the University of Chicago* (6) in which I brought out inaccurate statements made by Mr. Chapin in his own article published in a preceding issue (7). Specifically, in his article, Mr. Chapin had stated: "*Professor Rautenstrauch's publications prior to 1930 neither mentioned nor used the break-even chart.*" Now, in his letter, Mr. Chapin states: "*The first published break-even chart that Walter Rautenstrauch presents was in 1922.*" I am glad to see that Mr. Chapin thus acknowledges that he was misinformed when he wrote his article on "The Development of the Break-Even Chart."

With regard to Mr. Chapin's claims concerning the work of Henry Hess, I wish to offer the following comments:

First: The distinction between fixed and variable costs was discovered and presented in 1832 by Charles Babbage (1).

Second: The graphical presentation published by Henry Hess in 1903 was a remarkable and creative work. Mr. Chapin's statement that it was a "copyrighted break-even chart," however not only ignores the fact that Henry Hess never used the terminology "break-even chart," but, even more important, it also ignores the fact that Henry Hess' presentation could be used for break-even analysis only in some very exceptional cases and does not by itself constitute the break-even chart as it was developed by Walter Rautenstrauch and as it is used today for the purpose of break-even analysis.

Walter Rautenstrauch's break-even chart is the graphical presentation of the cost to sales relationship. It is based upon the concept of functional charting (plotting sales in abscissa and costs in ordinate, using the same scale). This was Walter Rautenstrauch's own idea. It had never been done before. It is this concept of functional charting which has gained such a wide acceptance in industry for Walter Rautenstrauch's break-even chart and also for his profit-and-loss chart which is based upon the same principle.

Finally, Mr. Chapin is certainly entitled, like any of us, to have his own opinion and to disagree with anyone else, but it is difficult to understand why Mr. Chapin chooses to ignore the fact that Walter Rautenstrauch, who actually developed his break-even chart shortly before World War I, has been so widely recognized as the originator of the break-even chart (2) (4) (5) (8) (9) (10). Among others, Waldemar Kaempffert, the recognized expert in the history of scientific developments, stated: "*Out of such research came the break-even chart, which is the invention of Dr. Walter Rautenstrauch . . .*" (3).

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(8) Editorials in *Modern Industry*, December 1948.

(9) Editorials in *Fortune*, February 1949.

(10) Manufacturing Series No. 207, American Management Association, January 1953.

—*Raymond Villers,*
Consultant to the Manufacturing Industries.

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PROFESSIONAL RELATIONS ACTIVITIES

The unanimous election of the AIIE to constituent membership of the Engineers Joint Council in February, 1958, is fairly common knowledge to most members by now. What may not be as widely recognized is the significance attached to this relationship—especially for the individual Industrial Engineer.

Wide spread professional recognition of the AIIE has been the goal of many men since Wyllys G. Stanton first founded the society. The realization of this goal began in earnest when a focal point for coordinated efforts was devised. This focal point came into being in 1955 at the St. Louis convention when a Professional Relations Committee was founded charged with the responsibilities of:

Advising the President and the National Board of Trustees of the AIIE on all problems concerned with coordination with other societies, institutions, and organizations in the field of engineering, science and management.

Participation in activities of joint interest, on behalf of AIIE.

Dr. Alex Rathe was given the responsibility of heading this group and it was largely through his efforts and the efforts of the men within this group that the AIIE in very short order was invited to sit in council with the other recognized professional engineering organizations that make up the Engineers Joint Council.

The Engineers Joint Council is a federation of professional societies representing a quarter of a million engineers. The general objectives of the Council are:

1. The advancement of the general welfare of mankind through the available resources and creative ability of the engineering profession.
2. The development of recommendations for sound public policies respecting national and international affairs wherein the engineering profession can be helpful through the services of the members of the engineering profession.

The attainment of these objectives requires the cooperation of the various branches of the engineering profession and the Engineers Joint Council seeks to promote this cooperation by:

1. Acting as an advisory and coordination agency to seek and study matters of mutual interest to the constituent societies of the Council.
2. Representing the constituent societies of the Council in those instances where joint representation is desirable.
3. Administering on behalf of the engineering profession, those activities authorized by a majority of the constituent societies of the Council.

In order for the AIIE to qualify as a constituent society, we had to show that a majority of our members were either engineering graduates of colleges of recognized standing or licensed by a state board of registration for professional engineers. In addition, our total membership had to exceed 5000 (which it now does by a healthy margin).

The Council accomplishes its work through committees made up of members from the constituent societies who have a specific interest in the problems studied by that particular committee. In 1958, the AIIE will be participating in 17 such groups. Our activities in these committees will be presented in future issues of the **Journal.**

A brief review of some of the major committees and their assigned responsibilities will indicate the breadth of the activities undertaken by the Engineers Joint Council.

The National Engineers Committee

This group is the working body through which the Council functions in its relations with the United States Government. This committee may appoint task committees for the specific studies in cases where the engineering profession may enhance the public interest.

Committee on Engineering Sciences

The Council set up this group to cooperate with the National Science Foundation in initiating and developing basic research in engineering sciences. Engineers Joint Council is thus performing one of its primary functions by speaking as, and getting its constituent societies to act as, a unit for the profession.

Labor Legislation Panel

The primary responsibility of this panel is to review the aspects of labor legislation which affect the profession of engineering and report to the Board of Directors on matters appearing to require action.

Committee on International Relations

This group serves as the working body through which the Council functions on international activities and through which the Council conducts its dealings with foreign engineering societies and engineers.

National Water Policy Panel

The National Water Policy Panel is authorized to take such steps as may be indicated from time to time to encourage the adoption of a coordinated national policy in the field of water resource development.

Engineering Manpower Commission

This commission is charged with the responsibility of developing policies and procedures to aid in establishing the importance of engineering to the national economy, to aid in maintaining the supply of trained engineers, and to promote the most effective utilization of engineers in support of the national health, safety, and interest.

The Commission is authorized to collect funds from industry and employers of engineers to carry out the purpose of the Commission.

Atomic Energy Panel

The impact of nuclear engineering on the various branches of engineering is studied and evaluated by this group. Appropriate recommendations may be submitted to member bodies of the Engineers Joint Council, to congressional committees, to the Atomic Energy Commission, or other governmental agencies.

Committee on Employment Conditions

This committee collects and prepares for distribution data regarding the economic and social conditions of employment of engineers.

Committee on Honors for Engineers

The Honors Committee is responsible for developing methods by which distinguished engineers may receive suitable recognition.

In addition to the above committees there are other groups concerned with:

Air Pollution
Consulting Practice
A National Engineer's Register
The Practice of Engineering
Recognition of Specialties in Engineering
Who's Who in Engineering

There are several committees directly concerned with the guidance and administration of EJC internal affairs such as Membership and Executive committees.

A third area of interest is the joint activities carried on by the Engineers Joint Council with other national and international groups:

The EJC—ECPD Survey of Engineering Profession
The Nuclear Congress Policy Board
EJC—American Institute of Architects
The President's Committee on Scientists and Engineers
Secretariat for the U. S. Committee on Large Dams
The U. S. National Commission for UNESCO
The Cooperative Committee for the Teaching of Science and Mathematics
Secretariat for the U. S. National Committee of World Power Conference
The American Association for the Advancement of Science

This brief outline serves only to indicate the broad range of the Engineers Joint Council activities in attempting to meet its objectives. The AIIE, in the future, will be playing an increasingly active part in these activities. The **Journal** will report on the work being done by the Engineers Joint Council and more specifically, the effect of these activities on each member.

Reported for the Professional Relations Committee
By O. J. Feorene

CALENDAR

January 24, 1959: Personal Development Workshop featuring Ray Montsalvatge; Skirvin Hotel, Oklahoma City. Write: Terry S. Leard, 4425 N. W. 11th Street, Oklahoma City 7, Oklahoma.

January 26-27: Conference sponsored by the Relations with Industry Division of American Society for Engineering Education, University of Houston. Theme: "Industry Speaks Its Mind on Engineering Education."

January 26-30: Advanced Industrial Engineering Intensive Courses, Washington University, St. Louis, Missouri. Write: University College, Washington University, St. Louis 5, Missouri.

January 26—February 5, 1959: Ten-Day Engineering and Management Course; University of California, Los Angeles. Write Reno R. Cole, Engineering and Management Course, College of Engineering, Room 3104, University of California, Los Angeles 24, California.

February 6-7: University of California's Eleventh Annual Industrial Engineering Institute will be conducted simultaneously on the Berkeley and Los Angeles campuses. Write: Department of Conferences, University Extension, University of California, Berkeley 4 or Los Angeles 24, California.

1958-1959

Oklahoma State University is conducting a series of seven management institutes for executives. The first was held October 30 and the second November 20. Topics have been selected for future dates as follows:

December 18—"Brainstorming for Ideas in Management"
January 15—"Building an Effective Communications System"
February 19—"Organization Planning and Executive Development"
March 19—"Organized Labor Today"
April 16—"Responsibilities of a Company President"

PERSONALITIES

ARTHUR E. ARONSON

Arthur E. Aronson, Manager of the Standards Department, A. B. Dick Company, and member of the Chicago Chapter, AIIE, was presented with an Award of Merit by the American Institute of Industrial Engineers.

John I. Herlihy, AIIE Chapter President, explained that the American Institute of Industrial Engineers annually selects a practicing Industrial Engineer who participates actively in civic affairs. "Art Aronson has given unstintingly of both time and effort to promote many worthwhile engineering and civic projects," Mr. Herlihy declared in presenting the award.

Mr. Aronson is a Past President of the Chicago Chapter of AIIE, Member Board of Governors, Chicago Technical Societies Council, Member of the School Boards in Wheeling and Arlington Heights, Illinois, and a leader in various youth projects in these communities.

NORMAN N. BARISH

Professor Norman N. Barish, chairman of the industrial and management engineering department at New York University's College of Engineering, has been named associate dean of the College. His appointment was announced July 1 by Dean John R. Ragazzini.

Professor Barish, an authority on business systems and organization, served as acting dean of the College during the 1957-58 academic year. He has been secretary of the College since 1948.

Before coming to NYU in 1947, he was an engineering consultant, an industrial engineering supervisor for the Radio Corporation of America, and an economic analyst in the federal Office of Production Management. He holds bachelor's degrees from the City College of New York and the University of Michigan, and a master's degree from the University of Pennsylvania. Professor Barish is the author of "Systems Analysis for Effective Administration" and co-author of "Case Studies in Industrial Management." In addition, he has written numerous articles for professional and business journals.

He is past president of the New York chapter of the American Institute of Industrial Engineers and an active member of several other professional groups. He also holds membership in four honor societies: Phi Beta Kappa, Tau Beta Pi, Pi Tau Sigma, and Alpha Pi Mu.

AKRON CHAPTER

The Akron Chapter of the American Institute of Industrial Engineers held its annual ladies night dinner meeting on May 21, 1958, at the Chesterfield Inn Hotel, State Road, Cuyahoga Falls, Ohio. The group heard Mr. Roger R. Clouse, Vice President and Secretary of the Federal Reserve Bank of Cleveland, talk on the subject, "Executive Development—The Husband and Wife Team."

At the regular technical meeting on June 18, 1958, the Chapter sponsored a cost reduction panel discussion. The panel consisted of Mr. R. A. Jay, Assistant to the President, Goodyear Tire & Rubber Co.; Mr. Howard F. Doll, Vice President of Manufacturing, Lamb Electric Co.; Mr. E. A. Cafieno, Executive Assistant, Chrysler Corporation.

Also, at the June meeting, new Chapter officers were installed. This meeting concluded the Chapter's fiscal year. For October, the Chapter planned a five-day symposium entitled "Economic Areas for Industrial Engineers." The symposium was conducted by Mr. Lowell N. George, conference leader from the Office Management Training Program, Goodyear Tire & Rubber Co.

CENTRAL ARIZONA CHAPTER

In April, the Central Arizona Chapter held an all day seminar, with informative talks given by the local members. Mr. Donald

Teapole, of Reynolds Metals Co., spoke on "Quality Control" with emphasis on statistical methods of sampling plans. Mr. Merlin Vincent and Mr. Emil Karas, both of Goodyear Aircraft Corp., explained the Goodyear Aircraft System of Production Control and Scheduling. Mr. Gordon Edgar, of Telco Corp., spoke on "The Role of the Industrial Engineer and His Place in the Organization."

At the May meeting, members and their wives heard an extremely entertaining talk on "Work Simplification in Industry Applied to the Home," presented by Mr. Elliott Kaufman of General Electric Co. Mr. Kaufman humorously described his results in attempting to scientifically organize household chores.

Mr. Edward Varney, A.I.A., renowned Phoenix Architect, presented the "Plan for Progress" story to the chapter at the June meeting. Mr. Varney pointed out to the AIIE the areas where we might be of assistance in the program designed to insure orderly growth of this area.

A panel discussion of Quality Control took place, conducted by the following well qualified men: Mr. Reed Pennell, of Motorola, Inc.; Mr. Chet Vermilyea, of Goodyear Aircraft Corp.; Mr. Don Lewis, of Sandia Corp., Albuquerque, New Mexico; Mr. Walt Kidwell and Mr. Solon Bennett, of AiResearch Mfg. Co.

In July, our Chapter was conducted on an interesting tour of the Phoenix plant of the Reynolds Metals Co. The tour was capably directed by the plant's Chief Industrial Engineer, Mr. Robert Castle. This plant is the world's largest aluminum extrusion facility for the production of extruded aluminum shapes and drawn tubes.

CHATTANOOGA CHAPTER

The meeting in April was devoted to the subject of "Operations Research," and the speaker was Dr. Joseph Krol from the Georgia Institute of Technology in Atlanta. Guests in attendance included four members from the Middle Tennessee Chapter in Tullahoma. A paper on "Operations Research" was prepared by Dr. Krol and copies issued to each person who attended the meeting.

The May meeting was election nite and Ladies nite. Electric organ music and the presence of the ladies made a memorable social evening for the Chapter. The officers elected for 1958-59 are as follows: President, Robert Marye; Vice President, Joseph F. Gregory; Recording Secretary, James E. Deuel; Corresponding Secretary, James A. Prigmore and Treasurer, Richard N. Wilhoite. The Board Members are: Charles P. Wehman, David C. L'Heureux, David G. Dall, and George J. Awad.

The membership congratulated Past President, Dave Dall on his appointment to the post of Vice President, Southeastern Region for the coming year.

Chapter activity for next year will include work on a two-day Seminar, to be held in the early spring, probably in conjunction with the University of Chattanooga. Attention will also be given to the Chapter Development Program and to legal registration for members. Chattanooga is proud of its net increase of 12 members during the past program year, which was the greatest increase of all established chapters in the Southeastern Region. Eighteen Companies are now represented in the membership.

Plans were approved to continue meeting on the third Thursday of the month at the Hotel Patten for the 1958-59 year.

COLUMBUS CHAPTER

On May 27, the Columbus Chapter held their final regular meeting of the year at the Seneca Hotel. It was a non-technical meeting with emphasis on fellowship.

Mr. John Bowers, Manager of Engineering, Bell Sound Systems introduced us to the fascinating field of high fidelity and orthophonic sound reproduction via a very stimulating discussion and demonstration of various types of available equipment.

Chapter election results were announced at the meeting. The following men were elected to guide our group through the following year: President, John Parks, Surface Combustion Corporation; Vice-President, Wm. R. Gale, Owens Corning Fiberglas; Secretary, D. J. Worstell, Denison Engineering and Treasurer, Earl Adey, Jeffrey Manufacturing Company. Board Members are: John Martin, North American Aviation; Bernard E. Egger, Norman Products and Heber Newell.

Refreshments were served after the program and the fellowship enjoyed by the members and their guests was a fitting climax to a very successful year for this chapter.

GREAT SALT LAKE CHAPTER

THE FRANK GROSECLOSE AWARD PLAQUE AWARDED TO THE GREAT SALT LAKE CHAPTER FOR OUTSTANDING ACHIEVEMENTS IN 1958.

HOUSTON CHAPTER

"Effective Work Simplification Training" was the subject of the final program of a very successful series of technical meetings for the Houston Chapter. Other programs in the 1957-58 series have presented well-qualified speakers on such subjects as: "Labor's Views Toward Industrial Engineering," "Quality Assurance," "Problems in Connection with Relocation of a Manufacturing Plant," "The Learning Curve," "Job Evaluation," "Performance Standards for Materials Handling Operations" and "Organization for Operations Research."

An additional highlight of the closing meeting was the announcement of chapter officers for next year. They are: President, Robert H. Ralston; Vice President, Jack H. Huffman; Secretary, John B. Rogers; Treasurer, Harry Rauch; Directors, H. R. Belcher, R. E. Doherty, Carrington Mason and Jerry Tagg.

On June 21 members, wives, and guests were entertained with a social evening of dining and dancing at Ellington Air Force Base Officers Club.

The Houston Chapter, AIIE, and the Industrial Engineering Department, University of Houston, jointly sponsored the Fourth Annual Industrial Engineering Conference which was held in the Shamrock Hilton Hotel in Houston on November 7, 1958.

Mr. Phil Carroll, well-known professional engineer, author, and

newly elected president of the Society for the Advancement of Management, conducted the one-day session on cost control. His subjects were:

1. "Cost Control Through Time Study"
2. "What is the Measure of a Fair Day's Work"
3. "Management's Responsibility for Cost Reduction"
4. "Reduction of Overhead Costs"

Mr. Sam Scharff, Ernst and Ernst, Houston, was the luncheon speaker; and Dr. J. T. Elrod, Southwest Region Vice-President, AIIE, and Head of Industrial Engineering, University of Houston, was master of ceremonies.

INDIANAPOLIS CHAPTER

The Indianapolis Chapter, American Institute of Industrial Engineers concluded its 1957-58 activities with a May 13, 1958, meeting at the Marott Hotel, when new chapter officers were installed. Professor Harold Amrine, Head of Department of Industrial Engineering, Purdue University, and Regional Vice President of AIIE, gave an informal presentation in which chapter activities and proposals for future goals and accomplishments were discussed.

The Indianapolis Chapter was presented its charter by Mr. R. W. Updegraff, Vice President of the Central Region, on January 18, 1957. Thirty-eight charter members formed the new chapter, twenty-seven of which were new members of the Institute.

The inception of the Indianapolis Chapter of AIIE took place at a meeting October 26, 1956, at the Marott Hotel, and was organized by William E. Oliver, Chief of Production Incentives, Eli Lilly Company, Indianapolis, Indiana, and received assistance by several members of the Louisville, Kentucky Chapter. Seventy interested persons attended the meeting including Professor H. H. Young, President of the Central Indiana Chapter, "Doc" Eldridge, President of the Louisville, Kentucky Chapter, and D. A. Trenwith, representative from National Headquarters, AIIE, Columbus, Ohio. Temporary officers elected to get the new chapter organization in motion included: President, William E. Oliver, Eli Lilly & Company; Vice-President, G. Giambalvo, General Electric Company; Secretary W. E. Dickerson, Linde Air Products; Treasurer, Richard R. Hall, The Richardson Company; Constitution Committee, P. H. Sweet, Diamond Chain Company; Membership Committee, George Reimlinger, The Richardson Company.

The 1957-58 Indianapolis Chapter activities were bolstered by a full staff of committees including those for Programs, Membership, Arrangements, Publicity, Conference and Newsletter. Monthly meetings engulfed such programs as Plant Tours, Speaking Presentations, Panel Discussions and Conferences. Representative of these programs were: "The Right Answer To The Wrong Question" by Mr. William Swaggert, Head of the Economics Division of Battelle Memorial Institute, Chicago, Illinois; Dr. Gerald Nadler, Professor and Head of Department of Industrial Engineering, Washington University, St. Louis, Missouri, presented the theme "Industrial Engineerings Professional Development," a Panel Discussion headed by three speakers representing Indianapolis Industries, Mr. Dave Ford, Chrysler Corporation, Mr. William Schilk, Ford Motor Company and Mr. Ed Conn, Stewart Warner Company; and a comprehensive presentation on "Work Sampling Rated for Establishing Work Standards," by Mr. Don Culver, Eli Lilly Company, Indianapolis, Indiana.

Highlight of the 1957-1958 sessions was "The Power of Positive Industrial Engineering" Conference held March 6, 1958, at the Marott Hotel, Indianapolis, Indiana. This conference, conducted jointly by Indianapolis Chapter AIIE, Indianapolis Chapter SAM and Central Indiana Chapter AIIE, was headed by a list of ten speakers who encompass the fields of industry, business, engineering sciences and education. Subject areas included Cost Reduction, Union Attitudes, Human Relations, Machine Replacement, Statistical Applications, Work Simplification and Wage Incentives. The speakers enjoyed by more than 100 conference participants included: Professor Harold A. Amrine, Head of Department of Industrial Engineering, Purdue University; Dr. Howard J. Fralish, Assistant Superintendent Engineering, Western Electric Corporation; Mr. David Dolnick, Consultant, Labor-Management Relations; Mr. Lowell Holmes, Executive Director Management Research Associates, Indianapolis, Indiana; Professor Ralph Swalm, Associate Professor of Industrial Engineering, Syracuse University; Dr. Charles Hicks, Associate Professor Mathematics, Purdue University; Mr. James F. Emerson, Head of Wage Incentives, Procter & Gamble Company; Mr. Floyd W. Simerson, Factory Management Department, Sears Roebuck & Company; Mr. Charles Winkleman, Management Consultant; and Mr. James F. Lincoln, Chairman of the Board, Lincoln Electric Company, Cleveland, Ohio.

The outgoing Officers and Committee Members have presented a real challenge to the newly elected Officers and new Committees, which the latter have surveyed thoroughly and are approaching the 1958-1959 term with planned programs which hold promise for the same quality and educational activities displayed by the former years programs.

Newly elected officers installed May 13, 1958, are: President, Stanley E. Roberts, Western Electric Company; Vice President, Richard R. Hall, The Richardson Company; Secretary, M. S. Burden, Allison Division, G.M.C.; Treasurer, Tom Collins, Western Electric Company; Board of Directors, Phil H. Sweet, Diamond Chain Company; Don H. Gray, Western Electric Company; William E. Oliver, Eli Lilly Company and W. E. Dickerson, Linde Air Products. Outgoing officers were: President, William E. Oliver; Vice President, George Reimlinger, The Richardson Company; Secretary, W. E. Dickerson; Treasurer, Richard R. Hall; Board of Directors, Richard L. Hawkins, Eli Lilly Company and Irvin E. Poston (at large) General Motors Technical Center, Detroit, Michigan.

LOUISVILLE CHAPTER

On April 16, the Louisville Chapter met at Bellarmine College for a dinner meeting. Principal speaker for the evening was Dr. Marvin Mundel, whose topic was "Memo Motion Analysis." Marvin Garrett, Chapter President, announced that a scholarship for one year's tuition at Speed School would be given by our chapter to a de erving freshman student. The winner's name was to be announced at the Engineering and Scientific Council Banquet.

The May meeting, our annual Ladies' Night, this year took the form of a plant tour through the *Courier Journal-Louisville Times* Company. Conducted tours were timed so that members, wives and guests could see the presses in action. Mr. Basil Caummisar of the newspaper staff presented an explanation of the operation.

Officers of the Louisville Chapter for the 1958-1959 term are: President, Sterling H. Durst; First Vice President, John K. Rigby; Second Vice President, Herbert E. Rogers; Treasurer, Raymond B. Robison and Secretary, Don W. Fuller.

METROPOLITAN NEW YORK CHAPTER

At the closing meeting of the year Henry Owades, outgoing President, presented the Annual Report on Chapter activities.

Highlights of the report were the increase of 109 members to a new high of 459, and the increase in the number of events from 42 to 70. Included in the 70 events were 10 monthly programs, four ten-week courses, two Workshop Seminars and two Plant Inspection trips.

In the area of Student Affairs, the New York Chapter has instituted two student awards to be presented annually to an outstanding member of the graduating class at Columbia University and New York University. The award at Columbia has been

named in honor of the late Prof. Walter Rautenstrauch, and the New York University award has been named in honor of Prof. David B. Porter. First awards will be made in 1959.

In conclusion Mr. Owades stated that the experience gained in making managerial decisions, in experimenting with new Industrial Engineering techniques, in establishing close relationships with some of the best Industral Engineers in the area are the compensation for the time and effort expended on behalf of the Metropolitan New York Chapter.

MIDDLE TENNESSEE CHAPTER

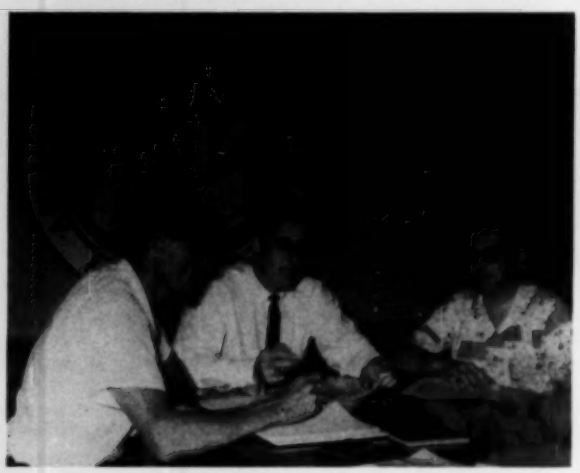
The following write-up appeared in the *Tullahoma News and Guardian*, Friday morning, June 27, 1958.

Ernest Teasley, of Manchester, is the new president of the Middle Tennessee Chapter, American Institute of Industrial Engineering. He succeeds Ed Prather, of Tullahoma.

Mr. Teasley is an employee of ARO Inc., contract operator of Arnold Engineering Development Center. He works in the propulsion wind tunnel facility at the air center.

Other officers are Bob Koger, vice president; Tom Bigger, secretary; Cord Link, treasurer; Miles Maynard, program chairman; Don Bean, membership chairman; Earl Leech, publicity chairman, and Ed Prather, constitution chairman.

OKLAHOMA CITY CHAPTER



New officers for the Oklahoma City Chapter of AIIE are: Hugh Dean of IBM, Treasurer; Terry Leard of S. W. Bell, President; and Norris Griffith of Western Electric, Secretary. Sam Austin of Tinker AFB, Vice President, was not present.

PHILADELPHIA CHAPTER

Our last meeting of the 1957-1958 season was held on Wednesday evening, May 21. The speaker for this meeting was Dr. Edward M. Westburgh, who spoke on the subject of "A Management Evaluation and Merit Rating Plan." Dr. Westburgh is Chief of the Psychological Service and Chief Psychological Consultant of the Department of Mental Diseases, Pennsylvania Hospital, Philadelphia, Pennsylvania. In addition to his educational training, Dr. Westburgh has gained considerable knowledge and experience in dealing with the problems of management development programs and organizations gained through numerous consulting assignments in industry.

Job evaluation refers to the importance of jobs within an organization regardless of the money value attached to them. It is not a scientific measure but is based on informed judgment using objective approaches. Most job evaluation schemes involve a form of comparison. Certain factors which are common to all jobs are isolated and defined. Point values are assigned to these factors. The degree of each factor present in a job determines the total point value. These point values may be assigned in one of three ways: 1. Straight point values; 2. Multiple values; or 3. Weighted values. These point values are plotted and a curve drawn. The number of job classifications are established by increments of point values. Money values are then assigned to the job classifications or for each increment in the scale.

In many instances a merit rating system is used in conjunction with the job evaluation program. The factors used in the merit rating program should be the same as those used to evaluate the jobs. According to Dr. Westburgh, the basic gains from job evaluation are uniformity, objectivity, and equity. Evaluation of a job should be performed by one who knows what the job is and not by a committee. The plan should not be so elaborate so as to be time consuming in its application. By the same token neither should the jobs be grouped merely to reduce the number of classifications.

As part of the discussion period which followed his lecture, Dr. Westburgh described a plan he is currently working on for a firm in the area.

Prior to the start of the formal meeting, Mr. Frederick A. Cline, Jr., as the outgoing president, was presented with the Past President's Pin.

SAN FRANCISCO-OAKLAND CHAPTER

Our chapter, 222 members strong, wishes to extend an invitation to any and all out-of-town AIIE members who are in the Bay Area on our monthly meeting nights to join us. We meet the first Thursday of the month at the Hotel Claremont in Berkeley for 6:30 dinner and an 8:00 meeting hour.

There is a "get acquainted" coffee hour after every meeting sponsored by our chapter. This custom, which started on an occasional trial basis, has proved so successful and rewarding it has now become a regular part of every session. It presents a wonderful opportunity to continue any discussion of the evening's subject on an informal, relaxed basis. It also provides a fine chance to get better acquainted with our fellow members.

The August meeting was keynoted by Mr. Lew Bohnne, prominent local restaurant management consultant. The problems of economical menu planning and efficient restaurant layout were presented and thoroughly discussed. The pros and cons of steam table vegetables, efficient bartending and why a rare filet minón sometimes turns up at the table well done were among the more interesting points of the talk. It was quite refreshing to consider the principles of our profession as applied to this field.

In July, Mr. Walter Tait of the Standard Oil Company of California gave a very fine talk on "Group Dynamics." This presentation was a mixture of speaking and leading our entire group in an experiment and discussion relative to the subject.

Two outside projects actively pursued by our group are professional registration by Industrial Engineers and sponsorship of the San Francisco Junior Achievement program. Professional registration is certainly a subject familiar to all of us.

Our chapter's sponsorship in the Junior Achievement program has been a very worthwhile and satisfying one. We provide speakers at the Junior Achievement advisor training sessions and also counsel the individual J. A. companies, upon request, to help in their "production" problems. The chapter provided the committee to select the "Best Production Company" in the San Francisco J. A. Center and our President, Hal Downie, presented the award plaque to the winning company, Novelties Unlimited, at the annual J. A. banquet.

Right now we are anticipating a dockside tour aboard one of the Matson Navigation Company's Hawaiian cruise ships. Naturally, the wives will be invited on this field trip.

TOLEDO CHAPTER

The Toledo Chapter of the American Institute of Industrial Engineers announces its program for the coming year. According to Mr. S. Sponder, Program Chairman, the theme will be "Cost Reduction." Speakers and topics are as follows:

The first meeting held on Tuesday, September 23, was Management Night, featuring the editor of *Steel Magazine*, Mr. W. J. Campbell, speaking on "Lets Beat the Cost Crisis."

Following in October, the President of the National AIIE Organization, Mr. G. H Gustat, talked on "The Scope and Broader Aspects of Industrial Engineering." Mr. Gustat is associated with the Eastman Kodak Company of Rochester, New York.

The November meeting will feature a panel discussion on "Cost Reduction Through Man Power Control." The moderator will be Professor M. Netter, Jr., of the University of Toledo Industrial Engineering Department. Panel members will be Mr. D. Dettinger, Assistant Chief Industrial Engineering at the DeVilbiss Company; Mr. W. Miller, Plant Industrial Engineer at Libbey-Owens-Ford Glass Company; Mr. L. King, Quality Control Supervisor at the Unitcast Corporation; and Mr. J. Schneider, Chief Industrial Engineer at the Toledo Stamping and Manufacturing Company. Discussions will be centered around selecting, directing, controlling, utilizing, evaluating, motivating, and compensating of employees.

To start the calendar year 1959, Mr. B. L. Hansen will speak on "Recent Techniques in Work Measurement." Mr. Hansen is Director of Research at the National Institute of Management located in Cleveland, Ohio.

The topic for the February meeting will be "Fitting a Cost Reduction Program To Your Company's Needs." Speaker will be Mr. J. Ryan, Staff Supervisor with the A. T. Kearney and Company, Chicago, Illinois.

Mr. R. Boerner from the Textileather Division of General Tire and Rubber Company will be the speaker at the March meeting. He is Director of Industrial Relations and his subject will be "Industrial Engineering and Labor Contracts."

The April meeting will feature Mr. N. V. Reinfeld, Managing Director of the National Institute of Management, as speaker. His topic will be "Inventory and Production Control Techniques."

The final meeting of the 1958-59 season will have Mr. W. W. Wittlinger of the Kimberly-Clark Company, Neenah, Wisconsin, speaking on "The Executive Approach to Industrial Engineering." Mr. Wittlinger holds the position of Manager of Professional Service.

The Toledo Chapter meets regularly on the fourth Tuesday of every month, September through May. Officers for the ensuing year are: Mr. D. Dettinger, President; Mr. J. Schneider, Vice President; Mr. F. Metzger, Secretary; and Mr. V. Caligiuri, Treasurer. Board members are: Messrs. A. J. DeMars, L. King, W. Miller,, J. Schneider, C. Janowiecki, S. Sponder, C. Cowles, and R. Cubbedge.

UNIVERSITY OF MISSOURI STUDENT CHAPTER

A student branch of the American Institute of Industrial Engineering was formally installed at Missouri University on April 22, 1958. The installation banquet was held in the Memorial Student Union at Columbia, Missouri

Dick Palmer was toastmaster for the occasion. He introduced Dean Huber O. Croft, Dean of the School of Engineering and Doctor Ralph L. Scorah, Chairman of the Department of Mechanical Engineering. Both of these men extended their congratulations to the new chapter and their best wishes for its future success. The Chapter was also honored to have Mr. Jack Sheehan the President of the Washington University Student Branch as its guest. He spoke briefly of the activities of the Washington University Chapter and gave a few suggestions to help get the new chapter here at Missouri off to a good start.

Presentation of American Institute of Industrial Engineers Charter to University of Missouri Student Chapter. Left to Right. James Schloemann, Secretary-Treasurer; Carl Wesemann, Student Chapter Chairman; Professor Robert M. Eastman, in charge of Industrial Engineering; Bruce Hudspeth, Vice President.

Mr. Palmer next introduced Dr. Robert Eastman, as the man most responsible for the founding of the new chapter of AIIE. Dr. Eastman spent a few minutes discussing future plans for the chapter and read a telegram of congratulations from Charles Brennan, Director of Student Chapters. He also briefly commented on the possibility of initiating a chapter of Alpha Pi Mu, the Industrial Engineering Honorary, on this campus, and then introduced the main speaker of the evening, Mr. Martin Bauer.

Mr. Bauer who is the President of the St. Louis Chapter of AIIE and Chief Industrial Engineer for Carter Carburetor in St. Louis, Missouri, presented the official AIIE Student Branch Charter to Carl Wesemann, temporary Chairman of the Chapter.

WASHINGTON, D.C. CHAPTER

The May meeting of our Chapter was held Tuesday, May 13, in the auditorium of the Perpetual Building Association. Mr. Stanley R. Kalin, Chief Industrial Engineer for National Plastic Products Company of Odenton, Maryland, was featured speaker. Mr. Kalin presented the history and structural basis for the work sampling technique, along with an audience participation demonstration designed to equip each participant to plan and carry out a work sampling study on his own. He explained how work sampling works, gave an example of the application of work sampling to an actual case, and discussed the effect of sample size on confidence limits. In addition, Mr. Kalin distributed a nine-page handout which included: graphical means to determine sufficiency of observations; random times for work sampling studies; a work sampling bibliography; and a work sampling demonstration and evaluation sheet therefor.

In an effort to increase the professional content of the agenda of each of the regular meetings, a brief professional development session is being scheduled on a trial basis. If, after a fair trial, these sessions prove to be of benefit, they will be conducted as a regular part of all meetings. The *Journal of Industrial Engineering* will be used as a text for these sessions. The first of these will start promptly at 8:00 P.M. and end at 8:15 on March 13 and the article, "Button, Button, Who's Got the Button?" in the

November-December 1957 issue of the *Journal* will be discussed. Mr. John R. Immer will lead the discussion. In succeeding months other articles from the *Journal* will be selected for discussion and, wherever possible, discussion leaders will be obtained from our own membership.

WESTERN VIRGINIA CHAPTER

The April meeting of the Western Virginia Chapter #81 of AIIE took place on April 9, when 30 members met at the War Memorial Building in Vinton, Virginia. Associate Professor R. L. Smith of Virginia Polytechnic Institute led an interesting discussion on Statistical Concepts for Organizational Control.

On May 14th the Chapter met at the S&W Cafeteria in Roanoke and heard Donald M. Loyd, Specialist of Communications and Community Relations, General Electric Company, Lynchburg, present a talk on Communications.

The Western Virginia Chapter suspended activities during the summer. Regular monthly meetings resumed in September.

YORK CHAPTER

The first annual ladies night banquet was held by the York Chapter on May 28, 1958. Our guest and principal speaker, National President, Gordon Carson, installed the new officers and directors for the coming year.

York Chapter Officers and Guest. Left to Right: Jerry Byrem, One Year Director; Art Wagenknecht, Two Year Director; R. Sheirer, Two Year Director; Jack Schofield, Outgoing President; Gordon Carson, National President; Jack Sweers, Incoming President; Ray Bloom, Vice President; Daniel Hess, Secretary and Charles Whittaker, Treasurer.

Mr. Carson's speech, "New Frontiers of Industrial Engineering," highlighted the evenings entertainment.

A stag outing for members and prospective members will be held by the Chapter on June 27, 1958.

BOARD OF TRUSTEES' MEETING

STATLER-HILTON HOTEL
LOS ANGELES, CALIFORNIA
June 13, 1958

The Board of Trustees of AIIE is the official governing body of your organization. This group meets to conduct business for you twice a year. The official minutes of the June Board of Trustees' meeting are published in the Journal *to keep you informed of AIIE activity.*

President Carson called the meeting to order at 9:20 A.M.

Attending: Gordon B. Carson, President; Frank J. Johnson, First Vice President; F. J. Titler, Executive Secretary; H. E. Emerson, Board Member; E. L. Slagle, Board Member; F. F. Groseclose, Board Member-at-Large; A. W. Rathe, Board Member-at-Large; H. T. Amrine, Vice President, Central Region; A. L. Chilman, Vice President, Western Region; H. L. Davis, Vice President, Northeastern Region; J. T. Elrod, Vice President, Southwestern Region; J. T. French, Vice President, Southeastern Region; M. E. Mundel, Vice President, Midwestern Region.

And: J. D. Nordahl, Board Member-at-Large Elect; W. J. Vallette, Vice President Elect, Northeastern Region; L. J. Broyles, Chairman, Resolutions and Awards Committee; E. Paul Lange, Executive Secretary, EJC; Henry Owades, UET Representative, Professional Relations Committee; Don J. Olsen, Professional Relations Committee; Andrew Schultz, Jr., Director of Research; Gerald Nadler, Chairman, Research Information Committee; Howard M. Dickason, General Chairman, Los Angeles Conference; J. L. Southern, President of Trustees of the Dwight D. Gardner Scholarship Fund; Vernon D. Foster, Director of National Programs.

1. *Minutes of the August 24, 1957, Board of Trustees Meeting* were approved as presented.

2. *The Dwight D. Gardner Scholarship Fund*—Mr. J. L. Southern, President of the Trustees of the Dwight D. Gardner Scholarship Fund, made a report on the organization and operation of the fund. He outlined how the fund was started, the progress made to date in collecting money and outlined what constitutes eligibility to receive scholarships. He said that it is planned to grant a scholarship this year. He ended by making a plea that all members and friends of AIIE donate to the fund by sending checks to the AIIE National Headquarters Office.

3. *United Engineering Center*—Mr. Henry M. Owades, Director of United Engineering Trustees Affairs for the Professional Relations Committee, reported on the history of the proposed building and explained the need for and some of the problems having to do with obtaining the 501 (c) (3) tax classification. Messrs. Rathe and Lange assisted in answering questions regarding the progress made in obtaining the required tax classification, the situation with regard to the building and EJC's progress in obtaining the same tax classification.

4. *Fund Raising for UEC*—President Carson opened the subject by mentioning the action of the Executive Committee at its meeting on May 17, 1958, which reads as follows:

> That the Executive Committee authorize the starting of planning for the fund raising campaign, this to be implemented after the acceptance by the Executive Committee of a Letter of Intent" from the United Engineering Trustees.

He explained the reason for the "Letter of Intent" by saying that there were two points on which the Executive Committee had had some reservations: 1. A guarantee of AIIE's continuous occupancy of the building and 2. Provision for AIIE to have a voice in the management of the building after it is completed.

The UET have assured us by letter that such a "Letter of Intent" will be furnished covering these two points.

After much discussion it was moved by Mr. Slagle, seconded by Mr. Davis and passed that "we immediately initiate a fund raising campaign for the UEC, such campaign generally to follow the recommendations of a consulting firm."

5. *Constitutional Amendment—Tax Classification*—Mr. Titler reported that Gen. Dargusch, who is our attorney handling the tax classification problem, has pointed out the need for a change in the "purposes" clause of our Constitution and By-Laws to make it possible for us to obtain this classification. He distributed copies of Mr. Dargusch's recommendations for a revision to our Constitution and By-Laws for this purpose.

Questions were answered by Mr. Lange and after considerable discussion it was moved by Mr. Johnson, seconded by Mr. Davis

and passed that the "Proposed Amendment be approved by the Board of Trustees and submitted to the members for a vote."

6. *Space for AIIE in the United Engineering Building*—Mr. Titler reported that the UET would require by July 15, 1958, a definite statement of the space that we will require in the new building for the period 1960-75. Since the space we require will be allotted to us when we first occupy the building in 1960 it would be necessary for us from that time on to pay rent on the basis of the requirements for 1975.

To determine as accurately as possible from the figures available for past operations and by projecting our expected growth to 1975 a study made by National Headquarters to provide figures for the consideration of the Board. He explained the several calculations which were used to determine our space requirements showing that they will increase year by year until 1975 when 2450 sq. ft. will be needed. This figure was presented as a recommendation of the Headquarters office for submission to the UET. It was seconded by Mr. Emerson. After thorough discussion and an amendment by Mr. Davis which was seconded by Mr. Johnson, the following motion was passed: "That we increase the recommendation of National Headquarters from 2450 sq. ft. to 2800 sq. ft. and that the latter figure be reported to UET as our requirments for 1960-75."

7. *Chapter Development Program*—Mr. Johnson made a short report on this program and the Frank Groseclose award which was awarded to the Great Salt Lake Chapter. He moved that "The Board recommend to the Editorial Board of the JOURNAL that a picture of the Frank Groseclose Award Plaque be inserted in the JOURNAL." Motion passed.

8. *Advertising in the JOURNAL*—President Carson reported on the progress that has been made with Dwight Early and Sons toward getting an active campaign started to acquire advertising for our magazine.

Mr. Gordon Early will start a field trip for this purpose about July 1, 1958. His trips incur an expense of $200.00 per issue of the JOURNAL which is in effect a drawing account. As soon as the sales of advertising result in commissions exceeding $200.00 this payment will drop out and we will pay him only for the commissions earned.

This campaign is to be handled in a very careful and dignified manner in keeping with the quality of our JOURNAL. The maximum amount of advertising has been limited by the Board of Trustees to 25%. However, it is not expected that this figure will be reached in the near future as a great deal of promotion work will be necessary to interest sufficient advertisers.

9. *Listing JOURNAL in the Industrial Index*—Mr. Elrod asked where we stand in regard to having the JOURNAL listed in the *Industrial Index*. Several of the members reported that their latest information indicated that our listing would be given favorable consideration in the next publication of the *Index*.

10. *Revision of Constitution of EJC*—Mr. Rathe introduced the subject by explaining that the need for a change in the EJC Constitution involved tax classification, EJC's incorporation in the state of New York and a change in the representation of the constituent member societies of the EJC. He said, however, that there would be no change in the operating purposes of the EJC, and answered questions concerning the use of the title "Engineering," the liability of AIIE and other constituent societies under the new Constitution.

It is necessary that the governing boards of three-fourths of the constituent societies approve this Constitution before it can be effective. Accordingly, Mr. Rathe then moved that "The Board approve the proposed EJC Constitution." It was seconded by Mr. Mundel and passed.

11. *American Institute of Plant Engineering*—The subject organization has applied to EJC for membership. President Carson said that this is an organization of approximately 1500 members on a national basis. They are engineers responsible for the mechanical maintenance, control and layout of plants and equipment. Their Constitution and membership requirements were reviewed by the EJC Membership Committee which approved the organization for membership and so recommended to the Board. Mr. Rathe moved that "The Board approve the recommendation of the EJC Membership Committee." It was seconded by Mr. Johnson and passed.

The Board of Trustees recessed for luncheon.

The meeting of the Board resumed at 1:30 P.M. at the call of President Carson and business was continued.

12. *Membership Report*—The Executive Secretary, referred to the published report carrying the membership figures and called attention to the total of 6,709 regular members. This figure includes, however, approximately 700 names which will be dropped for non-payment of dues.

He reported that membership applications are still coming in in large numbers. Applications are screened at Headquarters so that only 35%, on an average, are now being sent to MQC. The report was received.

13. *Financial Report*—Mr. Titler called attention to the total income figure of $94,674.00 as against a budget for the year of $101,610.00. The expense sheet showed a total of $58,082.00 for the year as against a total budget of $101,610.00.

While we are in good financial condition it must be remembered that during the remaining portion of the fiscal year income will be relatively small while expense will remain fairly constant, so that by the end of the fiscal year expenses and income will be more nearly in line with the budget for these two accounts. The report was received.

14. *Fellow Awards*—Mr. Broyles, Chairman of the Resolutions and Awards Committee, was called on to present his report. He said that the time between the appointment of his committee and the meeting had been too short to do full justice to the work. The committee, however, was able to screen all the applications that came in—a total of six. Of these, two individuals were recommended to receive the award.

Before completing the voting on these two names there ensued a lengthy discussion regarding the whole procedure of selecting fellows. It was pointed out that among the fellows elected in previous years there are two types of individuals; those who have many long years of outstanding service to the profession and those who are strictly honorary in nature. It became evident during the discussion that the difficulties we have encountered during past years stem from the fact that we have no specific definition for *fellow* and that there is probably a definite need for two levels or grades—an honorary grade and another grade. In view of these conditions and the lack of proper guides for selecting fellows it was felt that no selection should be made until definite procedures and guides had been developed. Accordingly, Mr. Mundel moved that the Board table the recommendations of the Resolutions and Awards Committee. The motion was seconded by Mr. Rathe and passed.

Mr. Broyles then presented a recommendation for a review of Section 2D of Article IV of our Constitution which provides for the selection of Fellows. After thorough discussion of his recommendation it was moved by Mr. Johnson, seconded by Mr. Chilman and passed that we return the proposal to the Committee on Resolutions and Awards for further study.

15. *Committee on Engineering Standards*—Mr. Rathe mentioned that a brochure by the Society for the Advancement of Management announces that their organization offers as a service the establishment of Industrial Engineering standards.

It was the consensus that this activity should be a function of AIIE and it was recommended to the new President that he give serious consideration to establishing a group for that particular service.

16. *Regional Boundaries*—Mr. Johnson reported on the results of his study of the areas serviced by the several Regional Vice Presidents. At various times questions have been raised by these officers as to how properly to handle those regions where the number of chapters has increased greatly and where traveling distance is great, making visits to all chapters difficult and the correspondence a considerable burden.

By reviewing the present and projected numbers of chapters throughout the country, Mr. Johnson's solution indicated that the number of regions should be increased from six to ten with new boundaries for several of the existing regions. A change of this kind was thought to be adequate for the next ten years.

The presentation was for information only, action by the Board not being required until the October meeting.

17. *Site for the 1960 Conference and Convention*—Following the usual procedure, President Carson called upon representatives from chapters who were bidding for the 1960 Conference and Convention to make their proposals. Representatives of the following chapters reported: Chicago, Dallas-Ft. Worth, Detroit and Metropolitan New Jersey.

Ballots were passed and, after counting, the Dallas-Ft. Worth Chapter had been selected.

18. *Papers by AIIE Members at Chapter Meetings*—Mr. Mundel asked the serious consideration of Regional Officers toward encouraging chapters to devote at least some of their meetings to papers by members of the chapters. These should cover projects in progress or completed projects which would be of interest to the membership.

19. *Research Committee*—Mr. Schultz, Director of Research, mentioned some of the items his subcommittees have been working on. He then raised a question regarding the papers which have been given at our National Conferences expressing the feeling of his committee that the programs presented have not carried sufficient technical sessions. He mentioned that several members of his committee have had a great deal of experience in setting up technical sessions and that this experience should be of value to the Program Chairman for future conferences. He moved the passage of the following resolution: "The Research Committee reaffirms its request for a tie-in between the Director of Programs of the National Conferences and the Research Committee." The motion was passed.

20. *Miscellaneous*—Mr. Johnson, First Vice President, being given the floor, made the following motions which were duly seconded and approved:

1. That it be a policy of AIIE that the Keynote address at each National Conference be given by the National President.
2. That pictures of all those who have been National Presidents of AIIE be obtained, framed and hung at National Headquarters.
3. That we establish a master schedule for chapter visits by National Officers to prevent overlapping.
4. That in view of the large potential source of income involved, AIIE establish a policy of having National Headquarters handle the sale of booths at the National Conference providing that in the opinion of our attorney such action would not conflict with the 501 (c) (3) classification.

President Carson said that it would be in order for the Board to commend the Los Angeles Conference Committee on the fine job it had done. A vote was taken and the recommendation was approved.

Mr. Slagle moved that "The manner of presenting the annual report this year constitute a policy for future years." Seconded and passed.

There being no further business, President Carson made the following statement before adjourning the meeting:

I would like to thank all of you for your cooperation during this last year. I have enjoyed working with every one of you. I can assure you that a one-year term in office is plenty. I hope you don't change that. If there is nothing else, we will adjourn. Thank you.

Adjournment—3:30 P.M.

CONFERENCE AND CONVENTION

The Tenth Annual National Conference and Convention of AIIE will be held:

Atlanta, Georgia

Hotel Biltmore

May 14, 15, and 16, 1959

"Y'all Come"

Recent Readables

AUTOMATION

"Punched-Tape Units Control New Type Transfer Line," by Staff, IRON AGE, *page 106, March 20, 1958.*

An electronically-controlled machine tool line, especially designed to bring automation economies to small and medium lot production, was unveiled last week in Los Angeles.

Essentially it consists of separate K & T "building block" units: one each for milling, drilling and boring. Each performs its machine functions on command from separate Hughes Digitape electronic control circuits. A transfer bar links the three machining stations.

The outstanding advantage of the setup is its flexibility for small-lot processing. Because each machining unit has its own tape control, parts can be intermixed on the line with no trouble at all. Within the machine limits, parts of a wide variety of sizes and shapes can be handled automatically.

"Let Automation Give Heavy Jobs a Lift," by Staff, IRON AGE, *page 104, March 20, 1958.*

Going all the way to automation is out of the question in many shops. The initial investment may be prohibitive. And there may be other limitations. But often even a heavy shop can cut costs and boost production by limited adoption of automation techniques.

A leading manufacturer of railway equipment applies this reasoning to selected processes when replacing obsolete equipment. A prime example discussed in the article, is a new machine to do a tough boring job on car wheels.

"Automation Works on Short Run," by Editors, IRON AGE, *page 74, March 20, 1958.*

Automation in manufacturing is often thought of as welding a company to a rather inflexible system.

It is common belief in industry that product runs must be long to justify heavy investment in automatic equipment. Companies who make several similar products, but in short runs, are especially inclined to think this way. Adaption to automation can be more a matter of product design and engineering than it is of product differences and short runs.

A good example of how one company tackled and solved the problem of making gasoline and diesel engines on the same automated production line is discussed in the article.

GENERAL

"Interlocked Factorials: Fewer Runs," by B. J. Reitzer and J. A. Brooks, CHEMICAL AND ENGINEERING NEWS, *page 40, May 5, 1958.*

The most data with the fewest tests—this is the problem engineers and scientists have to face when they plan experimental programs. Now a new design comes to their aid. Called the interlocking factorial design (all combinations of variables and levels). Yet it keeps all the advantages of the full design, according to its designers.

"Whatever Became of Merit Rating," Anonymous, PERSONNEL, *page 8, January-February, 1958.*

What's so wrong with the idea of paying more for better work? It's high time, says the author, to revive this dying concept.

The author examines, first, how merit rating came into being; second, what factors have contributed to its downfall; and, finally, what we could do to save the life of a sound and usable concept?

"Setting Salary Standards for Executive Jobs," by E. N. Hay, PERSONNEL, *page 63, January-February, 1958.*

Traditional job evaluation plans have generally proved unsuccessful in rating executive jobs. Here is an account of the thinking behind a method specifically designed to establish correct salary relationships at the higher echelons of management.

"Design for Hearing," by J. D. Vandenberg and C. T. Goldsmith, MACHINE DESIGN, *page 114, May 15, 1958.*

In the man-machine system, hearing ranks second only to vision as an information gathering sense. But, as a human-factors problem, hearing—or, more specifically, noise—often outranks vision, particularly since high-level noise can damage the ears, or cause accidents through interference with voice communication or warning signals.

When hearing effectiveness becomes a design problem, the first concern of the human-factors engineer is to make use of the ear's known characteristics to recommend tolerable noise levels, preferred pitch of signals, and best methods for carrying out intelligible verbal communication. Paralleling these efforts in the human-factors area are the familiar techniques for reducing the intensity of the offending noise source or for isolating and shielding it.

"Job Planning Halves Maintenance Time," by Staff, CHEMICAL WEEK, *page 51, February 15, 1958.*

Most firms have always had some sort of planned maintenance program to combat increasing labor and material costs, and for keeping process downtime to a minimum. This article affords an opportunity to compare effectiveness of maintenance programs with that of a program of Canadian Industries Ltd.

Key to the program is the preplanning of maintenance jobs down to the smallest possible detail. This planning provides the worker with a complete step-by-step rundown of job operations, a list of the materials, tools and equipment needed and the safety precautions to be observed. Also included: the amount of time required for the job.

The program is aimed at maximum utilization of labor. But it is not an incentive plan. The men are not asked to work harder or faster.

"Man and Machine," by J. D. Vandenberg, MACHINE DESIGN, *page 108, April 17, 1958.*

Presented here is the introductory article of a series organized to provide a human-factors background for the designer contending with human limitations and capabilities. Emphasis centers on defining areas of human-factors activity and showing how these areas fit into the overall design picture. In following articles, attention shifts to more specific topics. Among these are vision and its effect on display design, hearing, muscular performance, and body dimensions, all considered in their relationship to man-machine system efficiency.

QUALITY CONTROL

"Reliability and the Quality Control Engineer," by R. G. Fitzgibbons, INDUSTRIAL QUALITY CONTROL, *page 13, May, 1958.*

The purpose of this article is to acquaint the reader with a new field of industrial endeavor called Reliability. In this article the author reviews the reasons for such a new field, explains its methodology, and describes in what respects it is similar to, and

in what respect it is different from quality control

"The Technical Aspects of Quality Control," by C. A. Bicking, INDUSTRIAL QUALITY CONTROL, *page 5, March, 1958.*

This article discusses the general problem of the various steps the QC engineer must go through to establish routine control over an industrial operation.

"The Mechanical Lot Plot Templet," by E. W. Ellis, INDUSTRIAL QUALITY CONTROL, *page 15, March, 1958.*

The lot plot templet machine was designed by the author to eliminate the laborious calculations normally required for lot-plot acceptance sampling methods. He feels that now lot-plot can be really competitive with attributes plans.

"An Application of Variance Component Analysis in the Transistor Industry," by R. W. Anderson and A. W. Wortham, INDUSTRIAL QUALITY CONTROL, *page 11, March, 1958.*

Analysis of Variance, customarily used on experimental data to determine the major sources of variation and their interactions, is applied to a slightly different problem. Here it is used to analyze the magnitude of the effect on performance not only of individual transistors but also their combined effects in a receiver.

"Audit Testing: A Sound Investment," by C. W. Carter and L. C. Paulson, INDUSTRIAL QUALITY CONTROL, *page 8, March, 1958.*

In papermaking routine testing at various stages of processing controls the finished quality and errors in these tests are costly. Errors are also fairly easy to make, so to avoid the expense of multiple tests, audit testing is suggested as an economical and highly satisfactory method of assuring the reliability of the routine tests.

MATERIALS HANDLING

"Space Platform Protects Fragile Equipment," by G. Haskins, MODERN MATERIALS HANDLING, *page 108, April, 1958.*

A new pack for fragile electro-mechanical equipment features a floating platform within the pack to successfully eliminate shipping damage. Assembly time for the pack is 30 man-minutes compared with 6 man-hours for its predecessor. Tare weight is cut in half, and one standard size replaces 25 crate sizes.

"Mechanized Mail Handling," by Editors, MACHINE DESIGN, *page 22, May 15, 1958.*

In 1956, an estimated 48 billion pieces of letter-mail passed through the United States postal system. The trend continues upward—exponentially.

To manage this mountain of mail, the Post Office acknowledges that the day is long gone when manual methods were adequate. The speed of mail in transit has been stepped up by modern vehicles, and all kinds of machines now move mail in bulk. Individual pieces of mail present more stubborn problems, and today designers are hard at work to mechanize unit handling.

ORGANIZATION

"Reappraisal of Appraisals," by P. R. Kelly, HARVARD BUSINESS REVIEW, *page 59, May-June, 1958.*

The author argues that an executive's performance depends not on his own efforts alone, as so many appraisal systems seem to assume, but also on factors largely within the control of management. "The manager is not only a coach but also an administrator," the author writes, "and in both capacities his success is reflected in the performance of subordinates." The manager should not, therefore, try to appraise a subordinate in isolation. He should also appraise the influence of the organization—and of himself.

"Setting Up and Maintaining an Effective Job-Title Program," by D. D. Cantor, PERSONNEL, *page 42, December, 1957.*

Job Titles—once looked upon as the exclusive province of the personnel department—are more and more being recognized as a general management responsibility.

A job title system that will quickly prove its worth in better organizational effectiveness, salary administration, and employee morale can be established, says the author, by following these basic principles:

1. Titles should clearly indicate the field of activity and the relationship of the job to that field.
2. Titles must be uniform throughout the organization.
3. Titles must be kept current.
4. All jobs which are composed of basically the same or similar responsibiilties should carry the same title.

BOOKS

AUTOMATION IN BUSINESS AND INDUSTRY, *edited by Eugene M. Grabbe, The Ramo-Wooldridge Corp. 611 pages, published by John Wiley & Sons Inc., 440 Fourth Avenue, New York 16, N.Y., $10.00.*

This book contains information on the fundamentals of automation, new developments in automation techniques, and descriptions of automation system applications.

The material shows how the fields of feedback-control theory, instrumentation, analog and digital computation, and data processing are becoming integrated as automation is applied. Emphasis is placed on those applications of control systems which can perform both complex control functions and electronic data processing.

FEEDBACK CONTROL SYSTEMS, *by Otto J. M. Smith, 694 pages, published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y., $13.50.*

Here is a unified procedure for covering the analysis and design of all types of feedback systems. This book presents the relationship between the open-loop transient, sinusoidal, or statistical response, and the closed-loop transient, sinusoidal, and statistical responses. It is shown how from any one of these six responses, the other five can be computed.

Four major sections cover linear analysis, linear synthesis, steadystate nonlinear analysis, and nonlinear synthesis.

MODULAR MANAGEMENT AND HUMAN LEADERSHIP, *by Frank Pieper, Methods Press, Box 4090, Minneapolis 14, Ind. 288 pages, $6.50.*

The author believes that this book, for supervisors and foremen, will settle the issue of whether autocratic or democratic methods are better for work leadership because he shows how both are necessary and how each should be used for different people and different situations. Mr. Pieper condemns tricky human relations techniques that manipulate people and he recommends honest, aggressive leadership.

MANAGEMENT FOR ENGINEERS, *by Roger C. Heimer, 453 pages, published by McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N.Y., $6.75.*

The purpose of this book is to familiarize engineers with management decision-making processes. It sets forth day-by-day workings of a business firm both as an economic institution and as a co-ordinate organization of individuals. It considers the impact of costs, standards, equipment, and ethics upon engineering decisions.

Topics include the professional engineer defined, engineering ethics, professional recognition, organization purposes, partnerships, contracts and policies, operating standards, line and staff objectives, and prerequisites to decision making.

AUTOMATION AND MANAGEMENT, *by James R. Bright, 270 pages, published by and available from Division of Research, Harvard Business School, Soldiers Field, Boston 63, Mass., $10.00.*

This entire study has been directed toward answering the question of whether highly automatic manufacturing systems have created new and different problems for management. Three major sections of the book cover the nature of automatic manufacturing, experiences with mechanization, and critical areas of automation.

Contents include evolution of automation, qualities of mechanization, thirteen automation programs and their backgrounds and techniques, conception and design of automation systems, maintenance and management of downtime, problems with personnel, and impact of automation on sales. A final chapter sums up ten significant trends of current automation and their effects on the factory.

TOWARD THE FACTORY OF THE FUTURE, SPECIAL REPORT NO. 28, *96 pages, published by and available from American Management Association Inc., 1515 Broadway, Times Square, New York 36, N.Y., $1.75 per copy to members, $2.50 per copy to nonmembers.*

This report is intended to help manufacturing management prepare for a smooth transition from present to future techniques and facilities of manufacturing operations. It offers managers a guide by which advancements of their own companies can be measured and aids in establishing goals for further progress.

Topics discussed include the challenge of change, maintenance operations in the factory of the future, research and development, the purchasing agent of the future, impact of atomic energy on production processes, automation for the smaller company, and developing tomorrow's leaders.

SAMUEL GOMPERS: AMERICAN STATESMAN, *by Florence Calvert Thorne, Philosophical Library, New York, 1957, 175 pages, $3.75.*

An analysis of Samuel Gompers' philosophy of unionism by one of his confidential staff assistants. The book includes his views on union executives' responsibility, voluntarism, collective bargaining, and jurisdictional disputes as well as on discrimination, regimentation, and non-partisan political action. Liberal use is made of quotations from speeches, articles, and testimony before congressional and governmental committees.

STUDIES IN THE MATHEMATICAL THEORY OF INVENTORY AND PRODUCTION, *by Kenneth J. Arrow, Samuel Karlin and Herbert Scarf, Stanford University Press, Stanford, California, 1958, 340 pages, $8.75*

An excellent and extensive treatment of the mathematical approach to inventory control, but rather deep for the non-mathematical.

QUEUES, INVENTORIES AND MAINTENANCE; The Analysis of Operational Systems with Variable Demand and Supply, *by Philip M. Morse, John Wiley & Sons, Inc., New York, 1958, 202 pages, $6.50.*

The first of a series of OR books sponsored by the Operations Research Society of America, and the first book to present an extensive treatment of queueing theory. It will serve as a valuable handbook to those individuals using the queueing approach to problem solution.

PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE ON OPERATIONAL RESEARCH, *published for the Conference Committee by ORSA, Baltimore, 1957, 526 pages, $7.50.*

Proceedings of the first international conference devoted to operations research, held at Oxford, England, on September 2-6, 1957, attended by 250 delegates from 21 countries. Included are the presentations and discussion summaries.

FINITE QUEUEING TABLES, *by L. G. Peck and R. N. Hazelwood, John Wiley & Sons, Inc., 1958, 210 pages, $8.50.*

Intended to provide useful tables for the solution of a wide variety of queueing problems for finite populations from 4 to 250. The second in the OR series, sponsored by ORSA.

THE DIRECTION OF RESEARCH ESTABLISHMENTS, *Philosophical Library, New York, 1957, $12.00.*

The twenty papers and a summary of discussions of the first International Symposium on the Direction of Research Establishments held at the National Physics Laboratory, Teddington, England, on September 26-28, 1956.

TOP MANAGEMENT DECISION SIMULATION, *the American Management Association, New York, 1958, 126 pages, $4.50 ($3.00 for members).*

The AMA top management decision game has been designed to provide conditions under which a few hours of concentrated decision-making, under pressure, will equal years of actual experience. The book outlines the nature of management decisions, the use of system simulation, and the development and use of their decision simulation model.

PLANT ENGINEERING PRACTICE, *by the editors of Plant Engineering, Dodge Books, New York, 1958, 704 pages, $18.50.*

A practical and comprehensive handbook covering the major areas of plant engineering activity. Two hundred twenty-six detailed studies are organized into 13 sections: Site and Layout, Construction, Housekeeping and Safety, Materials Handling, Maintenance, Paints and Protective Coatings, Mechanical Power and Piping Systems, Electric Power, Utilities, Lighting, Heating, Ventilating and Air Conditioning, Instrumentation and Quality Control, and Shopwork. Well illustrated.

LINEAR PROGRAMMING & ECONOMIC ANALYSIS, *by Dorfman, Samuelson & Solow, McGraw-Hill Book Co., New York, 1958, 525 pages, $10.00.*

A general exposition of the relationship of linear programming to standard economic analysis, starting with basic concepts and progressing into advanced considerations.

BASIC MOTION TIMESTUDY, *by Bailey & Presgrave, McGraw-Hill Book Co., New York, 1958, 224 pages, $5.00.*

A rather complete exposition of BMT, its development and use, presented by the men who originated this particular system of predetermined motion-time data.

ENGINEERED WORK MEASUREMENT, *by Karger & Bayha, The Industrial Press, New York, 1957, 630 pages, $12.00.*

An extensive presentation of Methods Time Measurement. MTM and time and motion study are treated as complementary systems within the broad framework of establishing and using performance standards.

HUMAN ENGINEERING, *by E. J. McCormick, McGraw-Hill Book Co., New York, 1957, 467 pages, $8.00.*

Written primarily for engineers and managerial personnel, this introductory book covers the field of human engineering—the design of equipment and the adaptation of work environment for optimum human use.

THE ADMINISTRATIVE PROCESS, *by Robert H. Roy, The Johns Hopkins Press, 1958, 236 pages, $5.00.*

An interesting presentation of an Industrial Engineer's (and

an administrator's) views of many assorted management problems. Food for serious thought—for the Industrial Engineer and management people.

PARKINSON'S LAW—AND OTHER STUDIES IN ADMINISTRATION, *by C. Northcote Parkinson, Houghton Mifflin Company, Boston, 1957, 113 pages, $3.00.*

An unusual and humorous treatment of the inefficiencies that develop within many organizations.

OPERATIONAL RESEARCH IN PRACTICE, *edited by Max Davies & Michel Verhulst, Pergamon Press, N.Y., 1958, 201 pages, $12.00.*

A compilation of papers and discussions presented to the NATO Conference on Operational Research, Paris, April 7-12, 1957. An account of what O.R. can do, how various techniques have been applied to specific problems and groups of problems, and an extension to civilian and industrial applications.

A COMPREHENSIVE BIBLIOGRAPHY ON OPERATIONS RESEARCH, *by Operations Research Group, Case Institute of Technology, John Wiley & Sons, Inc., N.Y., 1958, 188 pages, $6.50.*

An extensive bibliography listing all known material on O.R. through December 1957, including approximately 3,000 books, articles, reports, proceedings, and 40 specialized bibliographies. No. 4 in the ORSA Publications in Operations Research series.

HANDBOOK OF AUTOMATION, COMPUTATION & CONTROL, *Volumes 1, 2 and 3, edited by Eugene M. Grabbe, Simon Ramo & Dean E. Wooldridge, John Wiley & Sons, Inc., N.Y., 1958, $17.00 each.*

A most valuable reference series in an important field. Volume 1 concentrates on Control Fundamentals, including sections on General Mathematics; Numerical Analysis; Operations Research; Information Theory & Transmission; and Feedback Control. Volume 2 concentrates on Computers and Data Processing, with sections devoted to Computer Terminology; Digital Computer Programming; The Use of Digital Computers and Data Processors; Design of Digital Computers, Design and Application of Analog Computers; and Unusual Computer Systems. Volume 3, to be released early in 1959, will include sections devoted to Systems Engineering; Manufacturing Process Control; Chemical Process Control; Industrial and Military Control; Servo Components, Sensors, and Transducers; and Design of Components.

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Just Out!

ENGINEERING MATERIALS HANDBOOK

Edited by CHARLES L. MANTELL, Consulting Engineer
Newark College of Engineering. *1906 pp., 648 illus., $21.50*

Each of the 43 sections was prepared by one or more specialists. A staff of 150 of these experts cover metals, organic materials, and inorganic materials. Emphasis is placed on the fabricated forms of materials, their physical and mechanical properties, their adaptations, advantages, limitations, competition with each other, protection against deterioration, and increase in their stability to withstand use and abuse.

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Edited by Byron K. Ledgerwood and the Staff of *Control Engineering*

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THIS practical working manual brings you step-by-step practices and procedures on all aspects of control engineering and design. You are guided every step of the way through system specification, synthesis and analysis, and evaluation. You get a complete run-down on pneumatic and mechanical control-function generators, servo wiring design, ac analog computers, and nonlinearities in control systems. Covers control systems engineering in both modern industry and the military, from the basic fundamentals to putting systems into actual practice.

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In addition, a monthly I. E. Opportunities Bulletin is supplied to over seventy chapters located throughout the United States.

Each job opening is assigned a **"P"** number for identification. The name and address of the person to contact for additional information concerning a specific job opening is sent to members on request.

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To list your job openings with the Opportunities Service, send all or part of the following information with the name of your contact man to the address below: Type of industry, location, job classifications, minimum educational and experience qualifications, and salary range.

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The following list shows job openings available just prior to press time. If you would like more information about one or more of the positions listed, mail the **"P"** numbers with your name and address to the Opportunities Service at the address below. The Service will advise you by return mail of the name and address of the person to contact for further information, or advise you if the position is no longer available. Your name will not be forwarded to the company with the job opening.

For more current listings, contact your local Chapter Secretary or Opportunities Chairman for the latest monthly Bulletin.

ADDRESS OF THE SERVICE

I. E. OPPORTUNITIES SERVICE
American Institute of Industrial Engineers
145 North High Street
Columbus 15, Ohio

INDUSTRIAL ENGINEERING OPPORTUNITIES

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required			
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range	
								from	to
1	Consult.	Ill	×	Broad			7–10	30	38
6	Warehouse	NJ		94					
17	Air Force	O		11, 13, 42, 31, 38	8.8		4–5		
20	Electric, Mfg.	Mo							
23	Education	NY		10, 50	6–10				
31	Paper Mill	Wis		11, 45, 80, 70, 32			1–5		30
34	Consulting	O	×	30, 40, 53, 71			4	27	
41	Consulting	O	×	10, 21, 31			5–7		
72	Airline	Ill		70, 42, 43					
79	Mining & Smelt	NM		10, 20, 30, 40	6–9				45
89	Foundry	Cal							
93	Foundry	Ill		15	8.4		5	25	40
119	Paper	Ga		10, 20, 30, 42, 43, 53	6.0–7.2				
123	Printing	NY		49, 53			2–4		
145	Lithography	Vt		31			2		
155	Electronics	Texas		11, 13			3–		
167	Weapons Systems	Wash DC		50		Ph.D.			
172	Power Shovels	Pa, Wisc, Ind		11, 13, 21, 32, 39					
181	Bldg. Maint.	Mich		31, 38, 48					
197	Aircraft	Wash		I.E.	6–11		2	25	40
198	Paper Converting	Mo		10, 11, 13, 19, 71	6–		5	30	40
199	Govt. Agency	Panama		Engr. Trainee	5.6–6.7			20	
200	Electronics	Texas		11, 31, 33, 35, 38, 54, 70	7.2–9.6		3–		
202	Electronics	Texas		11, 19, 33, 35, 38	6.5–8.0		5–		
203	Electronics	Texas		11, 19, 38	7.2–8.6				
209	Consulting	Ill-NY	×	50, 51, 52	9.0–15.0				
210	Mfg.	NY, NJ, Fla, Cal, Ill		54, 50 (Military)	10.0–15.0				
213	Aircraft Repair & Mod.	Cal		15, 32, 42, 43, 44,53	7.5		2½	21	
214	Airforce Depot	NY		13, 31, 40	4.4–7.4				
222	Education	Mont		37, 51, or 54	6.5–7.5		3	24	
223	Navy Ship Repair	Guam		94–42, 44, 48, 49	7.5 plus 25%				
226	Silverware	NY		92–13, 21, 42, 11			10	35	45
228	Navy Overseas Bases	Pacific		Preventative Maint.					
229	Bakery	Mo, Cal							
235	Knitting Apparel	NC		10–26	5–8		3–10		45
236	Printing	Ill		91–30, 50	12.0–14.5				

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required		
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range
								from to
242	Elect. Mfg.	Tex		91–11, 63	9–9.5		5	28 40
243	Food Processing	Tex		32 in Foods	6–7.5		3	25 35
244	Steel Ind.	Mich		10, 11, 13, 15, 21	5.3–5.8		0–2	23 33
246	Paper & Bag	Ala		33, 34, 35, 51, 54, 71, 73, 91				
247	Navy	Guam		92–13, 36, 42, 48, 70	8.8		3	
248	Auto Seat Covers	RI	×	95	12.0–18.0		5–10	32 40
249	Chemicals	WVa, Cal					5	25 35
257	Chem. Proc.	Pa, WVa, Va		10, 21, 43	Open		1–5	Open
266	Mining & Smelt.	NM		10, 20, 30, 40, 91	8.0+		5	33 43
267	Electronic Supply & Eng.	NY		10, 30, 40, 70	4.5–7.5		3	
268	Director of I.E.	Ill	×	43, 11	20.0–25.0		10	38 50
269	Mfg.	NY		31	18.0–			
270	Rubber Housewares	O		10, 11, 13, 42, 43	7.0–8.0		5	25 35
271	Syn. Fibers & Films	Pa, Va, WVa		10, 20, 42, 43			0–5	
273	Air Force	Utah		10 through 19	6.3–7.5		1½–2½	
274	Maint. Control	SC		11, 18, 52, 71, 90	7.5–8.2		2½	
275	Maint. Control	SC		11, 18, 52, 71	4.4–4.9		0	
277	Mfg.	NY, Ill		31	12.0–15.0			
278	Retail Chain	O		30, 42, 43, 71				35
279	Airline	Ill, Colo, Cal		11, 13, 42, 43, 70	5.0–8.0		2–8	
281	Education	Mo		10, 31				
282	Chemical	Fla		10–19, 30–39			–5	27 33
283	Electrical	Ia		14, 15, 18	6.0–7.0		0–5	20 30
284	Paper	NJ		81	–8.0		2–	
286	Textile	Ga		36				
287	Navy	Wash DC		44, 45, 49, 53, 54, 71	7.0–8.2		2½–	
288	Electronic	Tex		11	7.2–8.2			
289	Electronic	Tex		70	7.2–8.2			
290	Electronic	Tex		19, 36, 38	7.2–8.2			
291	Electronic	Tex		11, 13, 15, 16, 91	8.6–10.0			
292	Air Force	Pa		10, 11, 13–15, 18, 31, 32, 34, 36, 71, 91	7.5		2½	22
293	Air Force	Pa		10–19, 41–47, 49, 52, 54, 70–73, 90–92	7.5		2½	22
296	Research	Cal		42–45, 50–55	8.0–12.0		2–5	
297	Metal Fabricating	Conn		70, 54	6.0–7.5		1–5	25 35
298	Pulp and Paper	NC		35				
299	Education	Mass		10, 20, 30, 40, 50		M.S. or Ph.D.		
300	Consulting-Mfg.	Nationwide	×	10, 11, 29, 31, 36, 42, 71	8.0–20.0	B.S.–Prefer M.B.A.	7–	28 38
301	M. Consulting	Upper Midwest	×	Broad	10.0–14.0		5–	28 50
302	Missile Production	Wash		10, 30, 40, 50, 70	6.0–11.5		1–	
303	Air Force Depot	NY		13, 31, 40, 91	4.4–7.5		0–3	
304	Mail Order House	Wisc		15, 81, 94			3–	
305	Mfg.	O		11, 36	8.4–9.6			
177	Education	NY		50+Gen. I.E.		M.S. or Ph.D.		45
306	Automotive	Pa		91	7.2–10.8		7–10	
307	Automotive	Pa		52, 54, 70	6.6–9.6		4–6	
308	Automotive	Pa		19, 36, 38, 53	6.6–9.6		4–6	
309	Automotive	Pa		15, 22, 23, 26, 28	6.6–9.6		4–6	
310	Air Line	Colo	15%	11, 13, 18, 51, 52	4.7–7.0		2–	Open
311	Aircraft	Cal		11, 13, 15, 18, 33, 34, 35, 42, 43, 44, 47, 54, 71, 91, 92			5–	
312	Chemical	Colo		10, 11, 13, 36	6.0–8.4		0–5	22 35
313	Aircraft	O		42, 43, 44, 34, 18	5.4–7.2		1–	24 42

Key to Job Classifications

No.	Job Classification
10	Motion and Time Study
11	Methods Improvement
12	Suggestion Systems
13	Work Measurement and Perf. Stds.
14	Stop Watch Time Study
15	Std. Time Data Dev. & Applic
16	Predeter. Elemental Time Stds
18	Work Sampling
19	Estimating and Costing
20	Wage Payment
21	Incentive Plans
22	For Production Workers
23	For Non-Prod. Workers
24	For Supervisory Personnel
26	Job Evaluation
28	Wage Administration
30	Production Engineering
31	Production Control
32	Process Planning and Routing
33	Scheduling and Loading
34	Flow Process Charting
35	Inventory Control
36	Cost Anal. & Reduction
37	Statistical Quality Control
38	Budgetary Control, Standard Costs
39	Tool and Gage Design and Control
40	Plant Engineering
41	Plant Location & Expansion
42	Plant Layout
43	Material Handling
44	Machinery & Equipment
45	Specif., Select. & Eval.
46	Replacement
47	Automation
48	Plant Maintenance
49	Cap. Budget. Facil. Plan
50	Operations Research
51	System & Simulation with "Models"
52	Mathematical Analysis
53	Engr. Economy Studies
54	Auto. Data Proc. with Computers
55	Market Research & Forecasting
60	Industrial Relations
61	Personnel Administration
62	Personnel Testing
63	Personnel Training
64	Industrial Psychology
65	Labor Relations
66	Safety Engineering
67	Suggestion Systems
70	Systems and Procedures
71	Admin. & Operating Procedures
72	Organization Charts and Manuals
73	Records Admin. & Form Control
80	Product Design
81	Packaging
90	Management and Supervision
91	Industrial Engineering Supr.
92	Chief I. E. or Equiv.
93	Plant Engineer
94	Production Supervisor
95	Plant Mgr., Fact. Mgr., Works Mgr.
96	General Manager

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